AIEE PROCEEDINGS
Order Form
Pages 43A–44A

ELECTRICAL ENGINEERING

NOVEMBER 1950

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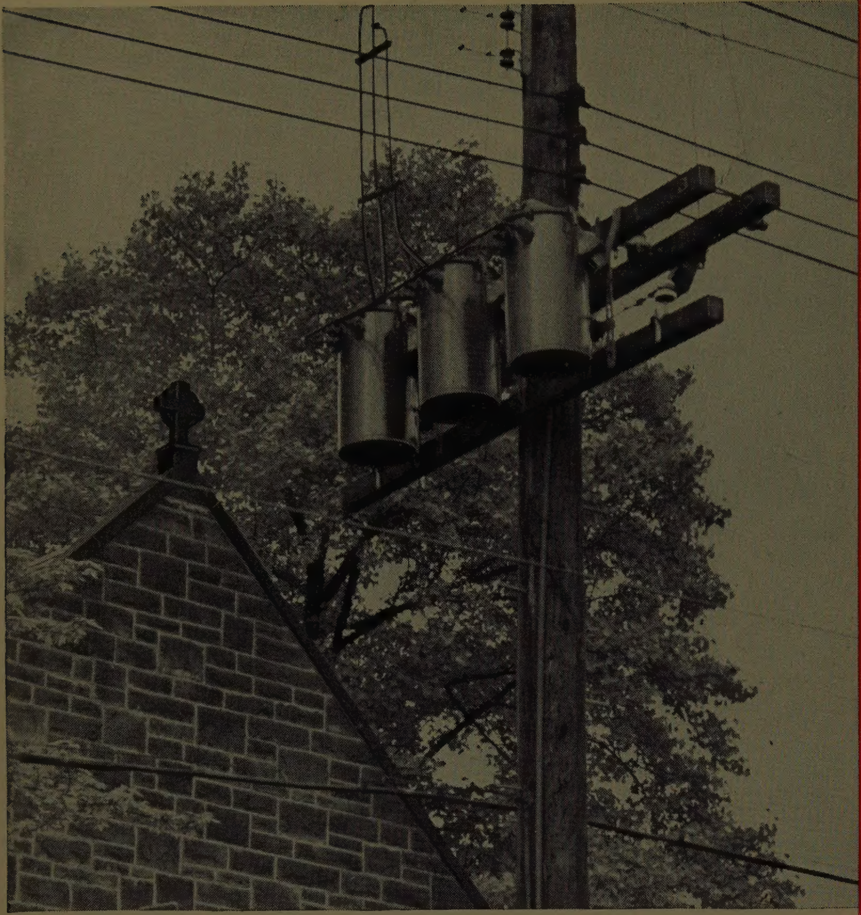
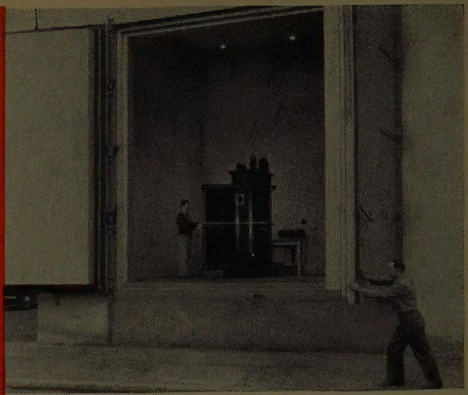
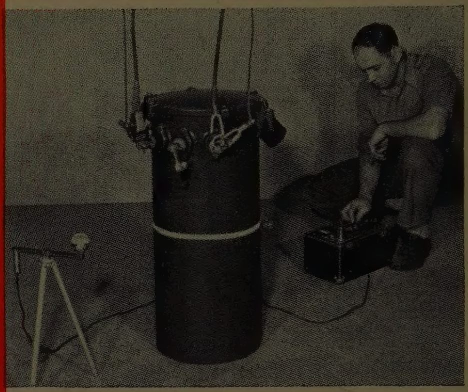




A 1000 kva power transformer ready to receive sound level tests in Allis-Chalmers Pittsburgh Works sound laboratory. Laboratory walls of concrete, glass wool and acoustical tile exclude 99.98% of exterior noise power.



Here a distribution transformer is getting sound and harmonic analysis. Physical noise level and harmonic index are new tools to measure sound energy. Transformer designs, in addition, are tested in accordance with ASA and NEMA standards.

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For details on Allis-Chalmers transformers contact your nearby A-C sales office or write for bulletins:

Bulletin 61B7309A — *ACP* (Allis-Chalmers self-protected) distribution transformers.

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Bulletin 61B6014A — Substation transformers, 50 to 500 kva.

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1950

The Cover: Airplane shown immediately after take-off. Note that the right propeller has been feathered, because of engine failure, to reduce drag on the airplane (story on *pp 953–8*). The Glenn L. Martin Company photo

Is the Engineering Graduate Educated?........................T. G. LeClair . . . 951
Automatic Feathering to Reduce the Hazard of Aircraft Engine Failure at Take-Off........................W. L. Kershaw . . . 953
Influence of Electrodes on D-C Breakdown in Gases at High Pressure........................J. G. Trump, R. W. Cloud, J. G. Mann, E. P. Hanson . . . 961
Low Noise and Distortion Audio Multiplexing Equipment With High Stability Carrier........................F. S. Beale . . . 968
Dielectric Relaxation in Liquids and Solids........................C. P. Smyth . . . 975
Asynchronous Transmission Capacity........................R. Gårding . . . 981
Long-Distance Power Transmission........................S. B. Crary . . . 984
Electrostatic Storage Tube........................S. H. Dodd, H. Klemperer, P. Youtz . . . 990
Safety Testing of Electronic Equipment........................O. G. Wedekind . . . 997
Machine Synthesis—An Encounter With an Idea........................T. C. Lloyd . . . 1001
Marking of Varmeters........................AIEE Committee Report . . . 1007
Fault Location by Pulse Time Modulation........R. W. Hughes, Nelson Weintraub . . . 1009
Lepeth Sheath for Telephone Cables........................A. J. Larsen, R. B. Farrell . . . 1014
Design of Broad-Band Transformers for Linear Electronic Circuits.H. W. Lord . . . 1020

TECHNICAL-PAPER DIGESTS

Ignitron Pulse Equipment for Particle Accelerators..........C. C. Herskind, J. E. Hudson . . . 959
Combined Phase and Ground Distance Relaying........................W. C. New . . . 960
A 5,000-Kva Underground Substation........................J. F. Sinnott . . . 965
Centralized Control of Steam-Electric Generators................J. A. Lind, J. M. Geiger . . . 966
Differential Relay Sensitivity Adjuster........................C. L. Headley . . . 967
Resistance Commutation........................F. D. Olney . . . 974
Measuring Water Velocity by an Ultrasonic Method........................W. B. Hess, R. C. Swengel, S. K. Waldorf . . . 983
High-Speed Supervision of Process Variables........................W. E. Belcher, Jr. . . . 996
Analogue Methods for Turbojet Thrust Instrumentation........................E. S. Van Valkenburg, N. W. Matthews . . . 1004
Voltage Changes Produced by Single-Phase Loads........................M. A. Faucett, Marvin Fisher, Jr., M. S. Helm . . . 1005
High-Voltage Ignitron Rectifiers........................M. J. Mulhern . . . 1006
High-Impedance Control Source for Saturable Reactor........................H. F. Storm . . . 1012
Tube-Type Totally Enclosed Fan-Cooled Motors........................R. C. Moore . . . 1013
Copper-Fin Totally Enclosed Motors....................L. A. Kilgore, J. F. Heidbreider . . . 1018
Tracking Radio Noise on Aircraft........................T. B. Owen . . . 1019

Miscellaneous Short Items: Measurement of Rate Drift of Timepieces, 982; Electrical Essays, 1025; General Electric Measurements Laboratory, 1027; Letters to the Editor, 1046

Institute Activities........................ . . . 1028
AIEE Personalities, 1038; Obituary, 1040; Membership, 1040

Of Current Interest........................ . . . 1042
New Books, 1046; Pamphlets, 1048

Industrial Notes........................ . . . 18A
New Products, 18A; Trade Literature, 48A

Index to Advertisers........................ . . . 64A

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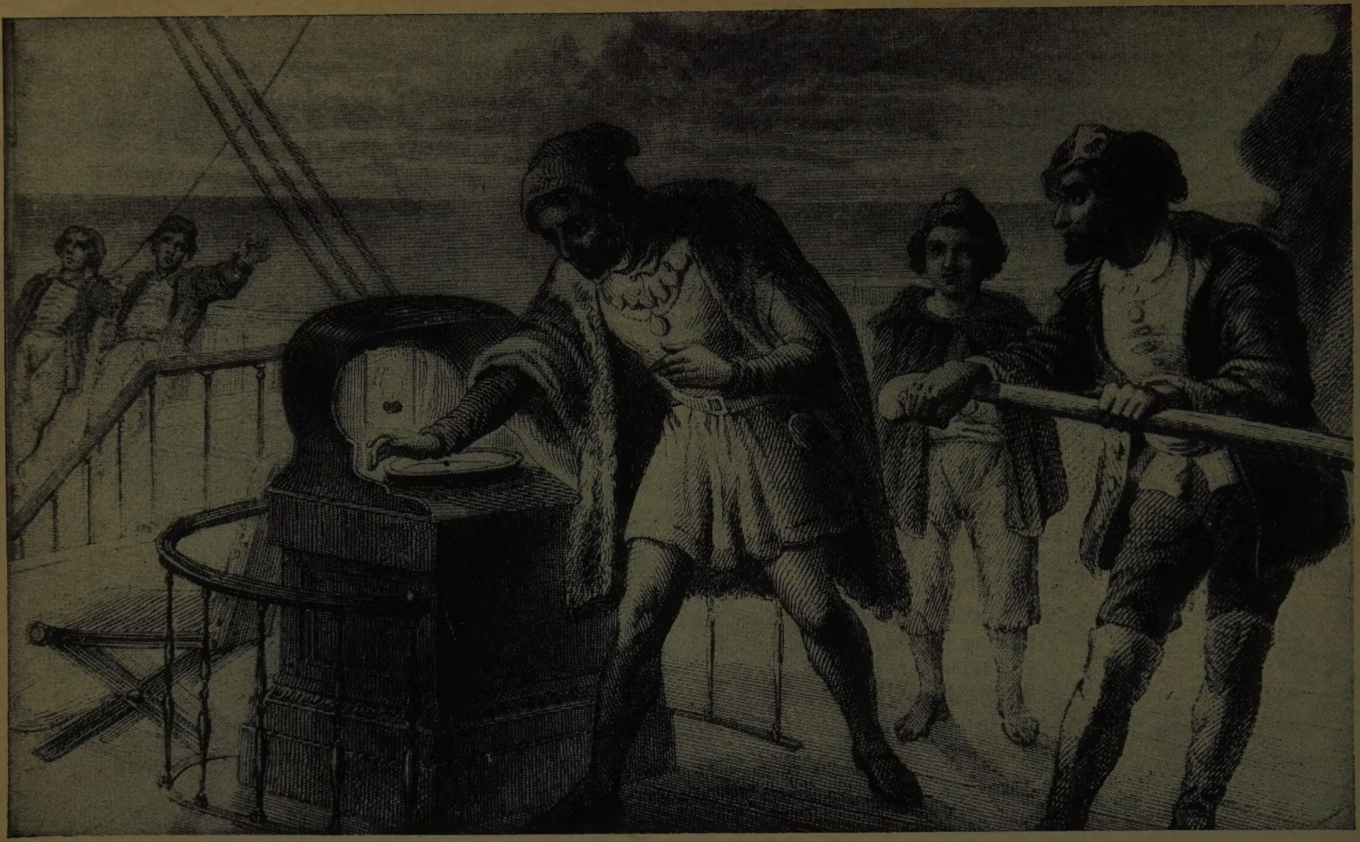

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HIGHLIGHTS ....

AIEE Proceedings. The latest AIEE *Proceedings* order form appears in the advertising section of this issue (*pages 43A–44A*). This form lists technical program papers presented at the AIEE Middle Eastern District Meeting held in Baltimore, Md., October 3–5, 1950; and the AIEE Fall General Meeting held in Oklahoma City, Okla., October 23–27, 1950. A list of order forms for *Proceedings* sections now being honored appears elsewhere on this page.

Is the Engineering Graduate Educated? President LeClair discusses the difficulties involved in planning a 4-year college course that includes adequate instruction in both liberal arts and engineering. He describes the part that professional engineering societies play in furthering a man's education (*pages 951–52*).

Automatic Feathering. An uninterrupted flow of power from the engines of an airplane is most important at take-off. An automatic feathering system, which eliminates any possible human error, is described (*pages 953–58*).

Influence of Electrodes on D-C Breakdown. A study of the effects different electrodes have on the breakdown of gases at high pressures is described this month. Included are tests of aluminum and stainless-steel electrodes in a variety of gases over a pressure range from atmospheric to 400 pounds per square inch gauge. Electrostatically generated constant voltages up to 900 kw were used (*pages 961–67*).

Low Noise and Distortion Audio Multiplexing Equipment. For distances up to about 50 miles, a need exists for a communication facility of multicircuit capacity because of growing congestion of the frequency spectrum and because of the increasing difficulty of applying carrier to the shorter power lines. A system which meets this need is described (*pages 968–73*).

News Index

Institute Activities................1028

Winter General Meeting Story..............1028
Future AIEE Meetings......................1028
Middle Eastern District Report.............1029
District 2 Prize Paper Awards...............1034
Committee Activities........................1035
Section and Branch Activities Annual Report..1036
AIEE Personalities..........................1038
Obituary....................................1040
Membership..................................1040

Of Current Interest...............1042

Congress Establishes New Electrical Values...1042
Future Meetings of Other Societies...........1042
Improved Carbon Resistor Developed.........1043
Letters to the Editor........................1046
New Books...................................1046
Pamphlets...................................1048

Relaxation Phenomena. C. P. Smyth, professor of chemistry at Princeton University and prominent authority on atomic physics, presents a discussion of the relaxation phenomena in liquids and solids. When the relaxation rate is very different from the rate of the phenomena causing the relaxation, the relaxation process may not be noticed; but when they occur at nearly the same rate, the relaxation phenomena become an important factor in the process (*pages 975–80*).

Asynchronous Transmission Capacity. The asynchronous transmission capacity of a motor, defined in this article as the maximum output which the motor is capable of developing when connected to a given point in a given power supply system, determines the ability of the motor to handle peak loads. A method for computing the asynchronous transmission capacity is described (*pages 981–82*).

Long-Distance Power Transmission. The determination of stability characteristics of long transmission lines, both with and without intermediate generation, is discussed by S. B. Crary of the General Electric Company's Analytical Division. In addition to performance of the system, the relative economics for the various methods of increasing the system power limits are described (*pages 984–89*).

Electrostatic Storage Tube. A new storage tube has been developed in the Servomechanism Laboratory of the Massachusetts Institute of Technology to serve as a reliable high-speed memory device for digital computers. This tube stores both zeros and ones as electric charges on the dielectric surface at one end of the tube (*pages 990–95*).

Safety Testing of Electronic Equipment. Safety considerations should be a routine part of adapting new techniques for the development of better electronic equipment. A program which assures the safe design of the finished product is described (*pages 997–1000*).

Machine Synthesis. The synthesis method of designing a motor directly for the physical characteristics which will yield a desired performance is contrasted with the theoretical method of obtaining a design and then analyzing it to determine its suitability. The applicability of the method is discussed for polyphase induction motors, single-phase induction motors, synchronous motors, d-c and universal motors (*pages 1001–03*).

AIEE Proceedings

Order forms for current AIEE *Proceedings* have been published in *Electrical Engineering* as listed below. Each section of AIEE *Proceedings* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *Transactions.*

AIEE *Proceedings* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 567–8; Jan '47, pp 82–3*). They are available to AIEE Student members, Associates, Members, and Fellows only.

All technical papers issued as AIEE *Proceedings* will appear in *Electrical Engineering* in abbreviated form.

Location of Order Forms	Meetings Covered
Nov '49, p 51A	Pacific General (1949) Fall General (1949)
Feb '50, p 46A	Winter General
Jul '50, p 30A	Winter General North Eastern District Great Lakes District Summer and Pacific General
Nov '50, p 43A	Middle Eastern District Fall General

Marking of Varmeters. The practices of a number of operating companies in marking varmeters are presented and discussed this month. Standards for the uniform marking of varmeters are desirable and a set of standards is recommended by the committee (*pages 1007–08*).

Fault Location by Pulse Time Modulation. An instantaneous determination of the location of a fault on a power line by measuring the time required for a wave to travel from the fault to a substation is described (*pages 1009–11*).

Lepeth Sheath for Telephone Cables. The manufacturing process of a new telephone cable sheath is described this month. This lepeth sheath consists of a jacket of polyethylene extruded on a paper-wrapped core, a layer of thermoplastic cement, and an extruded lead sheath (*pages 1014–17*).

Design of Broad-Band Transformers. This article by H. W. Lord of the General Electric Company, Schenectady, N. Y., describes a system which provides a common meeting ground between electronic engineers and transformer-design engineers (*pages 1020–25*).

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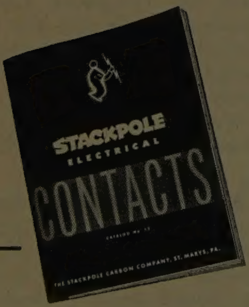

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Is the Engineering Graduate Educated?

T. G. LeCLAIR
PRESIDENT AIEE

President LeClair discusses the limitations of our present college educational system for engineers and suggests ways in which education can be continued after formal training is over.

WHEN I WAS graduated from high school at the ripe old age of seventeen, I was an educated man. On the practical side, I could repair an electric iron so it would work perfectly, and I could even climb an electric line pole and connect a wire without getting killed. On the literary side, I had written and delivered a valedictory address at my high school graduation exercises, more than half of which was in poetry. From then on, it was only necessary to collect the fruits of this education.

My father was quite an old fogy; all he'd ever done in life was to learn all about the timber business, which is backwoodsy sort of stuff, and to own and operate a sawmill. Just how he got along with his men, how he made his mill work, or where he got the customers for it were minor details in which I had not the slightest interest.

It was a fortunate accident that shortly thereafter a motorcycle I was riding encountered a horse and buggy, and landed me on my back with a broken leg. In those ensuing weeks, when the doctor said that I could not climb poles for some time, it occurred to me that I might just as well go to college before making that first $10,000.

At the end of those four years, it was astounding to me how much my father had learned. Instead of an old fogy, he seemed to be a man with some maturity and judgment. He was shocked not only that I listened to his advice, but even once or twice asked for it, particularly on the question of where I should go to get a job.

It was about that time that I began to wonder seriously when a man becomes educated, and I have been wondering ever since. Perhaps it will do no harm to ask some of you here today the answer to that question.

The ordinary college course leading to a Bachelor's Degree is approximately four years, and educators have a rather difficult task within that time to pour into a student what might be considered an education. It is a hard enough job in the arts colleges where the full four years are devoted to teaching you to live a broader life and have an understanding of the arts and sciences which make life more pleasant and the world a nicer place to live in. In an engineering college, the task is even more difficult. If an engineer is to become a reasonably well-rounded man and not merely a highly specialized technician, he must have a knowledge of the arts and sciences, he must be able to express himself, and he must learn how to think in general. In addition to that, the engineer must have enough education in his specialty in order to qualify to enter the profession.

In an engineering school, it is possible to absorb only a fraction of the liberal studies that are given to a student in a college of arts in such matters as history, foreign languages, and other general subjects. It is even difficult to cover the various specialties in engineering. Your deans, professors, and instructors hear a continual plea from the graduates that a student should be given more courses in modern material such as electronics, ultrasonics, atomic energy, nuclear fission, and other new material which was unknown 10 to 20 years ago. Other volunteer advisors make the opposite plea that a student should have more of the fundamentals such as mathematics, chemistry, physics, and so on. How can our colleges strike a balance between these two positions?

A compromise has been made in that the college course over the first two years, including basic arts and sciences and the fundamentals of engineering, is essentially the same for all branches of the profession. In the third year, the courses begin to spread out, but the mechanical engineers and the electrical engineers take courses that are very nearly alike. Even in the fourth year, there are many courses that are common to all branches of the profession. In other words, there is very little time to get more than a mere smattering of the specialties that are implied in the 90 different branches of the engineering profession which are important enough to form the basis of some professional engineering society.

Does this mean that at the end of four years of college, an engineer is not quite educated, not quite competent in the specialized profession that he is to enter? I think, perhaps, it does. This statement in no way belittles those persons responsible for our college education. It merely points out the fact that four years out of a full life of three-score-and-ten is entirely too short a period in which to get an education. Some men are fortunate enough to spend another two or three years on a Master's Degree and a Ph.D. in engineering, or some closely related subject, but on the other hand, a larger number have to face that mundane question "When do we eat?" and must get out into the working world and earn a living.

What is there yet to learn after graduation that is a necessary part of our development? If a new graduate is the holder of an electrical engineering degree, he must determine which particular specialty he will follow. Is he

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Essentially full text of an address presented at the Middle Eastern District Meeting, Baltimore, Md., October 3–5, 1950.

T. G. LeClair is Chief Electrical Engineer, Commonwealth Edison Company, Chicago, Ill.

going to be a power engineer or an electronics engineer? If an electronics engineer, will he go into radio broadcasting, radio receivers, or electronic heating? In whatever of those branches he may decide to specialize, he must decide if he is going to be a design engineer, a research engineer, a sales engineer, a teacher, an operating engineer, or take up any one of a hundred other fields of endeavor, including that of management.

After he has selected his specialty and found a position, he will discover that there is a great deal to learn about that particular field. It seems to me to be the job of the employer to teach the new man how to perform in his new field. Our industry has become so specialized that actually most businesses would rather have a young man without previous experience in order to train him not only in their specialty but in their way of going at their particular business, so that he may fit into their team properly.

Sometimes this training comes as a bit of a jolt. A man has been going from one course to another in widely different fields in college and suddenly discovers that all of his interests are concentrated on one particular specialty. If he happens to work in the electric utility industry with which I am, of course, the most familiar, he not only finds that he is working solely with the production of electricity and not the utilization of it, but that he is only designing overhead lines for the distribution system and knows very little about transmission, generation, or any of the other phases of the power problem. More than that, his efforts are confined within the organization and he may not have much opportunity to see how these activities affect others outside his industry. Right here is where many a good man succumbs to inertia. When he was in college, his courses were assigned to him and they were graded, and he knew whether he was progressing. On the job, most employers see that he performs the assigned task properly and that's all. Beyond this, it's up to the man. This may be a hard-boiled attitude, but I wonder if it isn't fair.

Any enterprise, whether it is a partnership, a business corporation, or even a governmental body, has certain fundamental obligations. In the case of a corporation, for example, that obligation is to produce a product and to make a reasonable return for the owners. Men are hired for their contribution to production and profit.

However, we, as individuals, have an obligation to ourselves to use a reasonable portion of the mentality with which we were endowed. No man is really happy when he is using a small fraction of his abilities. Should we not, then, use some of the 16 hours of the day for which we are not paid to learn a little something outside our working world? Perhaps we should read a little literature, go to new plays, or learn how to be helpful to our neighbors in community affairs. All this tends to broaden our knowledge, make us better citizens, and make us more satisfied.

Even to succeed in business, we must go a little beyond the requirements of the job at hand. By that I mean we must keep up with the current developments not only in our own field but in closely and distantly related fields, so that when a new problem arises we may call upon that store of other knowledge to bear on the problem at hand.

At this point, I can't resist calling the attention of this audience to the importance of your professional engineering society in furthering your education after the completion of college. There is no better way to keep up with the new developments in your particular field of engineering than to read the papers, go to the meetings, go to the conventions of your professional engineering society. The AIEE, with its 37,000 members, 45 technical committees, and the hundreds of papers that are presented each year, has something to offer that is new to every electrical engineer in whatever specialty he may be engaged. There is no better place to go to acquire this new knowledge. Some of it you may get firsthand from your colleagues in your particular job, but far more can be acquired from people in related industries all over the world who have given of their time to write papers that you may read. You may exchange ideas with your fellow engineers by working on committees, as soon as you have proved yourself willing and able to carry on this activity.

Your engineering society can be a very important factor in another part of your general education. Not the least of education is the ability to get along with other people. To do so, we must work with them rather than against them, and the engineering society is a remarkably helpful place in which to learn this. If you have a man on your payroll, you may order him to do something and he must do it because you have the power to compel him. But if you are working in an engineering society, you can only get people to do things because they like to do them, and because they wish to work with you. Nothing develops the ability to get things done tactfully, gracefully, and pleasantly quite so much as working in this type of volunteer organization where men work together because of mutual respect and a spirit of service.

It is a thought-provoking fact that only about a third of the practicing engineers in the country belong to any professional engineering society, and yet there is scarcely any well-known or top-grade engineer who does not belong to one. The joining of an engineering society preceded, rather than followed, their position of prominence in the profession. Did they progress because of joining an engineering society? Or, did the same good judgment that made them successful make them realize the importance of supporting their professional society? In either case, it is a good example.

Each time I read a technical paper on a subject with which I am not familiar and give it thorough study, I get a little feeling of uplift that here is something new and interesting that I should like to know more about. And here is something for which I can admire a fellow engineer who has had the ability to come forward with a new and valuable idea. It's just like being cooped up in a small room until we discover a door which can be opened. We open it into a new room of knowledge, look around, and find it a higher and wider room, and leading out of that are several doors into other branches of knowledge. No matter how far we go, we find higher ceilings and broader horizons, and more of the joy of living which comes with not only being better trained but with the knowledge and anticipation that we have much to learn and much farther to go to become educated men.

Automatic Feathering to Reduce the Hazard of Aircraft Engine Failure at Take-Off

W. L. KERSHAW
ASSOCIATE AIEE

An automatic propeller-feathering system is a necessity for reducing the hazard of failure of an aircraft engine on take-off, because to eliminate propeller windmilling drag the feathering cycle must be initiated before the pilot has any indication of engine failure. This article describes such an automatic feathering system.

FAILURE OF AN aircraft engine in flight changes the propeller of that engine from a source of thrust to a parasitic source of drag. Present-day propellers, selected for the efficiency with which they convert tremendous horsepower into thrust with comparatively small blade area, absorb proportionately high horsepower when windmilling the engine. The propeller used on the Martin model *202* airplane converts a maximum of 2,400 horsepower into thrust at take-off. The same engine and propeller combination exerts a drag equivalent to approximately 220 horsepower when being windmilled at take-off air speed. In contrast, the drag of the feathered propeller is equivalent to 12 horsepower. Thus, it is evident that in the event of an engine failure, in addition to the immediate loss of half the thrust, a windmilling propeller steals approximately 10 per cent of the horsepower available from the remaining engine, reducing the net thrust to approximately 45 per cent of normal. With one propeller producing drag and the other producing thrust, a turning moment exists, tending to turn the airplane in the direction of the faulty engine.

Take-off is in some ways the most critical part of a normal flight. With most of the runway used, the airplane is normally gaining both speed and altitude but has too little of either to permit any immediate landing maneuver. It is at this time that the pilot depends most on an uninterrupted flow of power from the engines. Of the multiplicity of instruments which confront the pilot, there may be none which will immediately and reliably tell him that one engine has ceased to deliver its share of thrust. Changes in directional and lateral trim are often the best indication of the trouble. Well-trained pilots generally diagnose the meager symptoms correctly, but the possibility of human error is definitely aggravated by the atmosphere of emergency resulting from engine failure during take-off. The proximity of the ground leaves no opportunity for recovery if the pilot feathers the propeller of the good engine. Such mistakes have occurred with disastrous results.

The automatic propeller-feathering system described in this article was designed to initiate the propeller-feathering cycle soon enough after engine failure to limit propeller drag to that of a feathered propeller, thus providing the maximum possible thrust for the remainder of the take-off and the landing approach to follow. Automatic feathering allows the pilot to devote his full attention to trimming the airplane, completing the take-off, and planning the best approach procedure. Electrically, the automatic-feathering system prevents the pilot from feathering the propeller of the good engine. The system to be described was designed for a 2-engine airplane and is based on 2-engine premises. Although the critical need for automatic feathering decreases as the number of engines increases, the device is capable of improving the reliability of all multiengine aircraft.

If, after an engine power failure, the propeller-feathering sequence is started while the propeller is rotating faster than windmilling speed and the propeller pitch is advanced rapidly enough so that actual revolutions per minute are maintained above windmilling revolutions per minute throughout the feathering cycle, part of the kinetic energy of the whirling engine and propeller can be converted into thrust to reduce the propeller drag during the feathering cycle to less than that of a feathered propeller. It has been determined experimentally on the Martin model *202* airplane (see cover photograph) that if the feathering cycle is initiated within two seconds after an abrupt loss of power, the propeller drag during the complete feathering cycle, starting at the instant of engine failure, will be less than that of a feathered propeller. If feathering is delayed 2.4 seconds after an abrupt engine failure, the windmilling propeller will start to produce drag, which will rapidly increase to full windmilling drag. Under the stress created by an engine failure during take-off, an average pilot requires five seconds or longer to initiate propeller feathering manually. After feathering has been initiated belatedly, the propeller will continue to produce a drag greater than that of a feathered propeller until the windmilling revolutions per minute corresponding to the changing propeller pitch are sufficiently less than actual revolutions per minute. Automatic feathering completely eliminates the time span during which the propeller drag exceeds that of a feathered propeller. This advantage of automatic over manual feathering may well determine

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Full text of paper 50-210, "Automatic Feathering—to Reduce the Hazard of Aircraft Engine Failure at Take-Off," recommended by the AIEE Committee on Air Transportation and approved by the AIEE Technical Program Committee for presentation at the AIEE Middle Eastern District Meeting, Baltimore, Md., October 3–5, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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whether or not the take-off will be successfully completed.

Figure 1 shows a time history of an automatic feathering cycle recorded in flight at an indicated air speed of 120 miles per hour, at altitude of 100 feet. One plot shows propeller revolutions per minute versus time. The time required to feather the propeller was 9.7 seconds, including 1.7 seconds before initiation of the feathering cycle. The feathering initiation and full-feather indications were obtained electrically. The second plot shows the impact pressure in excess of that caused by air speed measured by a pressure rake installed just aft of the propeller. The latter curve shows that the propeller did not create drag while it was being feathered.

Engine torque is used as the means of determining the need to feather a propeller. This method is applicable to any engine equipped with a torque nose, in other words, where the propeller gearing is so arranged that the full engine torque is transmitted through a ring gear which is prevented from rotating by a series of pistons working in oil-filled cylinders. The oil pressure thus developed, called torque pressure, can be measured at an outlet provided on the propeller gear case at the forward end of the engine. The automatic feathering system is so arranged that when it is turned on and when normal take-off engine torque is expected, the propeller will be feathered if engine torque drops below a preset value.

Engine revolutions per minute cannot be used to indicate failure because the windmilling revolutions per minute of the engine at take-off air speed are within the range of revolutions per minute which might be obtained with a faulty propeller governor. Even though engine revolutions per minute are lowered by a faulty propeller governor, the engine would continue to deliver power and feathering would be undesirable.

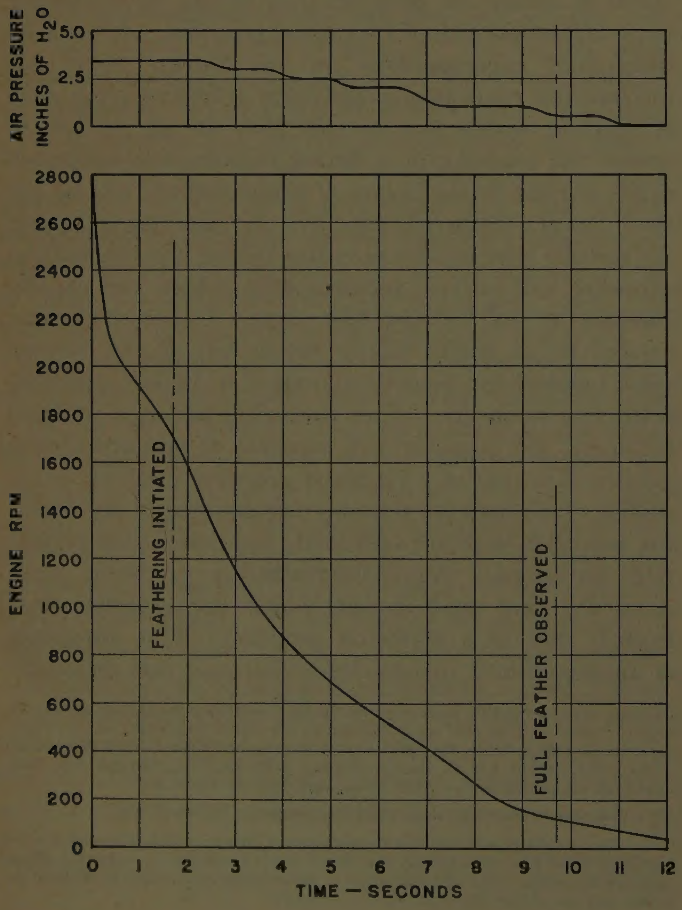


Figure 1 (left). Time history of an automatic feathering operation in flight. The indicated air speed is 120 miles per hour, and the altitude is 100 feet. The air pressure curve shows the impact pressure in excess of that due to air speed, measured aft of the feathering propeller

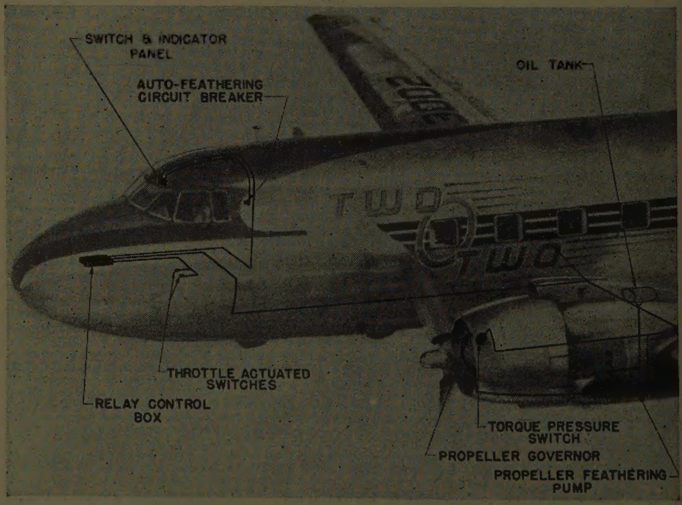
Manifold pressure is likewise of no use as a failure-sensing means, since it is proportional to engine revolutions per minute and throttle setting and does not depend on the actual firing of the cylinders and development of power.

The automatic feathering system used on the Martin model *202* airplanes was designed on the following premises:

1. The propeller of the engine should be feathered if, after an indication has been obtained that the engine is operating at take-off power and no change in engine controls has been made which would reduce engine power, it is determined that engine power has dropped below some prescribed minimum value and has remained below that minimum value longer than would be caused by a momentary engine cough or sputter.
2. The manual feathering system of one propeller should be rendered inoperative while the other propeller is being feathered automatically in order to eliminate the possibility of pilot error.
3. The automatic feature should be so designed that no component of the normal propeller-feathering system need be redesigned.
4. Failure of the automatic feathering system should not interfere with operation of the normal feathering system.
5. The pilot should be able to override the automatic system to unfeather the propeller if power is regained after feathering has started.
6. The automatic feathering system of the second propeller should be rendered inoperative after one propeller has been feathered either manually or automatically.
7. The automatic feathering system must not create any hazard or limitation during any feathering operation.

The following description of components of the automatic

Figure 2 (below). Phantom view of the airplane with the location of the major components of the automatic feathering system shown



feathering system applies to the Martin model *202* airplanes with Pratt and Whitney *R-2800* series engines and Hamilton Standard propellers. The system is applicable to any multiengine airplane equipped with engines each having a torque nose and propellers capable of being feathered.

The automatic feathering system, shown schematically in Figure 2, has four functions: arming, initiating, feathering, and remembering. They are performed as follows:

1. A throttle-operated snap-action switch, located in the engine control pedestal and provided to accomplish part of the arming function, indicates that the throttle is advanced a position of low take-off power.

2. A high torque-pressure switch, mounted directly on the engine, completes the arming signal when engine torque pressure exceeds 80 pounds per square inch (corresponding to 1,130 horsepower at 2,220 revolutions per minute), indicating the engine has achieved take-off power. The purpose of this switch is to preclude the possibility of inadvertent feathering during a throttle burst or during engine starting, at which time the throttle switch might be closed while torque pressure would be less than the setting of the low torque-pressure switch described later.

3. An arming relay is provided to maintain the armed signal as long as the throttle switch is closed, regardless of later torque-pressure decreases below the initial arming value of 80 pounds per square inch. The system can be disarmed only by retarding the throttle to open the throttle switch or by turning automatic feathering off.

4. A low torque-pressure switch, mounted with the high torque-pressure switch on the engine torque nose, completes the automatic feathering signal when torque pressure drops to 30 pounds per square inch, provided the system has been armed.

5. A time-delay relay is used to prevent initiation of the feathering cycle for those cases in which the power loss is of a momentary nature. A delay of approximately 0.2 second, in addition to the time required for torque pressure to drop to 30 pounds per square inch, has been found to be the best setting.

6. A feathering relay shunts the normal feathering controls to complete the feathering cycle, blocks the manual feathering system of the opposite propeller, and closes the remembering relay.

7. A remembering relay interrupts power to the corresponding engine fuel-booster pump and renders the automatic feathering system of the opposite propeller inoperative as long as the propeller remains feathered and the bus is energized.

8. A manual on-off selector switch to de-energize the automatic feathering system when its protection is no longer needed and three indicator lights, one to show power on and the others to indicate when each engine is armed, are grouped with the manual feathering switches within easy reach of both the pilot and copilot. See Figure 3.

9. The relays required for the 2-engine installation are located in the automatic feathering relay box located in the fuselage of the airplane. The box is provided with Cannon-type quick disconnects to facilitate testing and replacement. See Figure 4.

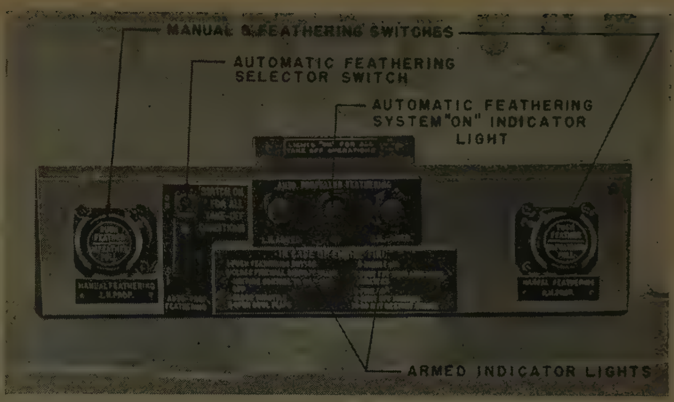

MANUAL FEATHERING SWITCHES
AUTOMATIC FEATHERING SELECTOR SWITCH
AUTOMATIC FEATHERING SYSTEM "ON" INDICATOR LIGHT
ARMED INDICATOR LIGHTS

Figure 3. Propeller control panel, showing manual feathering switches, automatic feathering selector switch, and indicator lights

Figure 5 shows the complete automatic feathering circuit and the manual feathering and unfeathering circuits of the Hamilton Standard hydromatic propeller. In this variable-pitch propeller, the pitch of the blades is controlled by the position of a piston within the propeller hub to which the blades are geared. In normal operation the position of the piston, and hence the propeller pitch, is controlled by a governor and valving arrangement using oil at moderate pressure provided by an engine-driven small-capacity pump, which is an integral part of the governor. To produce rapid pitch change while feathering and unfeathering the propeller, an electric motor-driven pump of greater capacity and higher pressure is used and the normal governor operation is by-passed.

The legend of Figure 5 will be used to designate the various relays and relay contacts in the following description of the operation of the circuit. The circuit is drawn with the propellers in normal operating pitch, throttles retarded, and torque pressure less than 30 pounds per square inch. The reversing circuits for the propeller are omitted because they have no effect on the operation of the automatic feathering system. The operation of the left engine circuits will be described.

With the selector switch off, all connections from the bus to the automatic feathering system are open and the engine fuel-booster pump control relays are grounded through the selector switch. When the selector switch is placed in the on position, the left fuel-booster relay is grounded through normally closed relay contacts LD_2 and power is available to the left throttle switch.

When the left throttle is advanced to a position corresponding to low take-off power, the left throttle switch closes, completing the circuit to contact *C* on the torque-pressure switch. Note that even though the torque-pressure switch is in the low-pressure position, no circuit is available to close the time-delay relay *LB* to initiate the feathering cycle. As torque pressure rises to 80 pounds per square inch, the torque-pressure switch closes on contacts *A* and *C*. The arming relay *LA* closes and is electrically locked in by its own contacts. This condition is indicated by the left armed indicator light. The purpose of the LA_1 relay contacts is to prevent an improper armed indication if some circuit element should present a resistance high enough to prevent relay *LA* from closing. The circuit

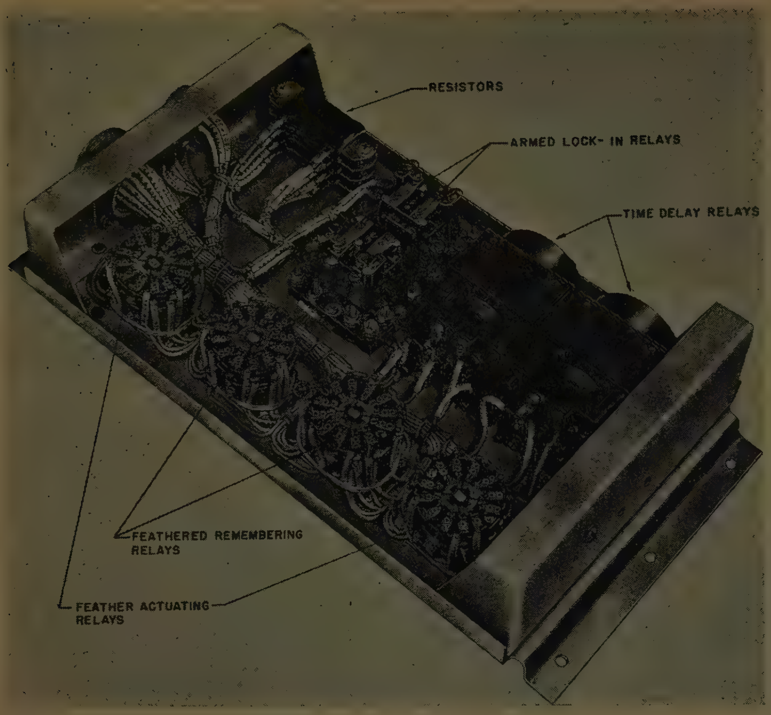


Figure 4 (above). **The automatic feathering relay box**

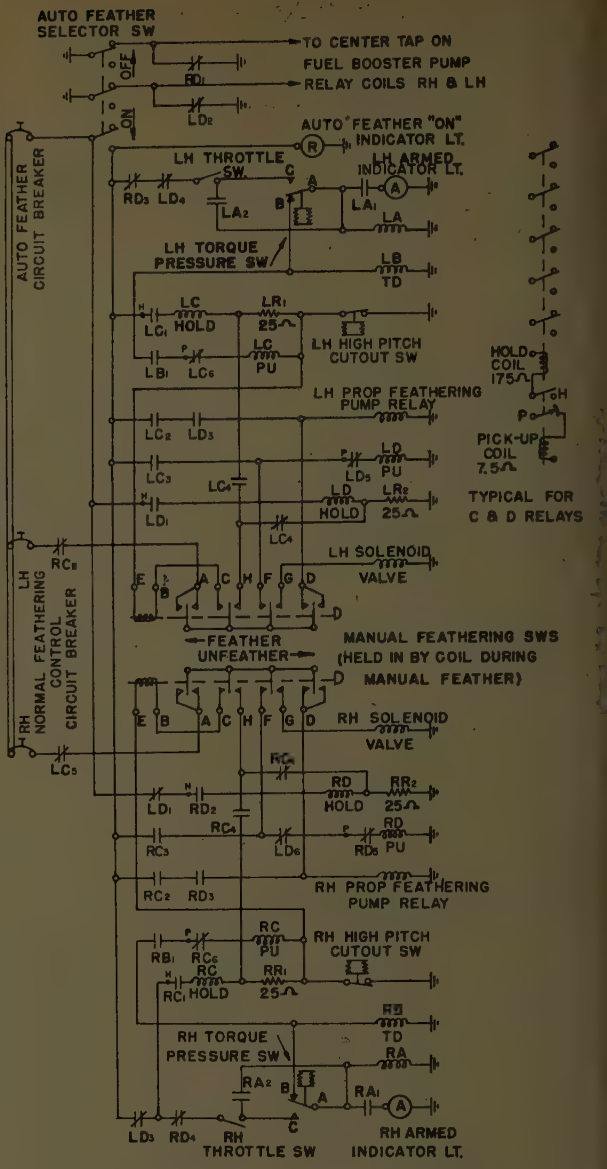


Figure 5 (right). **The automatic feathering circuit showing connections to the manual feathering and unfeathering circuits. LA, RA—left or right arming relay. LB, RB—left or right time-delay relay. LC, RC—left or right feathering relay. LD, RD—left or right remembering relay. PU—pickup coil. TD—time-delay coil. LR_1—left resistor number one (typical)**

is now armed and will feather the propeller if torque pressure should drop below 30 pounds per square inch. The circuit can be disarmed by opening the left throttle switch or by switching the selector switch to off.

If the circuit is armed and the torque pressure drops to 50 pounds per square inch, the torque-pressure switch will assume some intermediate position and open the connection between its contacts *A* and *C* but the circuit will remain in the armed condition. If torque pressure drops to 30 pounds per square inch, the torque-pressure switch will close on contacts *A* and *B*, energizing the coil of the time-delay relay *LB*. After an 0.2-second delay, contacts LB_1 close, energizing the pickup coil of the feathering relay *LC*. Contacts LC_1 close to energize the holding coil of relay *LC* before contacts LC_6 open to de-energize the pickup coil of relay *LC*. The resistor LR_1 is provided so that the *LC* relay may be dropped out by application of bus potential to the ground side of the *LC* relay holding coil during unfeathering. When relay *LC* picks up, the pilot cannot manually feather the right propeller while the left propeller is being feathered automatically and the pickup coil of the remembering relay *LD* is energized.

Contacts LD_1 close to energize the holding coil of relay *LD* directly from the bus before contacts LD_5 open to de-energize the pickup coil of relay *LD*. The resistor LR_2 provides a means to drop out the *LD* relay during unfeathering. Operation of relay *LD* starts the feathering pump, blocks the operation of the right-engine automatic feathering circuits, de-energizes the arming circuit of the left propeller and the relay *LC* pickup coil circuit, and opens the control circuit to the left engine fuel-booster pump. This last operation does not deny fuel to the left engine since normally the left engine-driven fuel pump will be operating. The fuel-booster pump is stopped to prevent loading the engine with fuel as the engine stops rotating.

With the circuit conditions as outlined, it is impossible to feather the right propeller either manually or automatically.

As the feathering pump moves the blades of the left propeller to the full-feathered stop, oil pressure increases to the value necessary to momentarily open the high-pitch cutout switch (a Hamilton Standard manual feathering system component). While the high-pitch cutout switch is open, the ground connection for the *LC* relay is removed and the *LC* relay drops out. The feathering pump stops, and the *LD* relay pickup coil circuit is de-energized. Contacts LC_5 close, permitting operation of the right-propeller manual feathering circuit.

The left propeller is feathered. The left remembering relay *LD*, electrically locked in by the connection through its own contacts directly to the bus, will prevent operation of the left fuel-booster pump as long as the selector switch is in the on position, and will prevent operation of the automatic feathering circuits of either propeller as long as the bus is energized, unless the left propeller is unfeathered. The *LD* relay has no effect on the operation of the right propeller circuits.

If the pilot desires, the left propeller can be unfeathered manually at any time during the automatic feathering cycle or after its completion. Assuming that the left propeller is being automatically feathered, it has been shown that the arming relay *LA* and the time-delay relay *LB* have been dropped out, while the feathering relay *LC* and the remembering relay *LD* are in the energized position. If the left-propeller manual feathering switch is pulled to the unfeather position, the following events take place:

1. Terminals *D*, *G*, and *H* of the manual switch are energized by a connection to the bus through the left propeller control circuit breaker, terminal *A* on the switch, and the common switching connection within the manual switch.
2. The *D* terminal provides a new direct source of power for the left feathering pump relay.
3. The *G* terminal provides power to actuate the left propeller solenoid valve. This valve, located on the propeller governor, reverses the oil flow for unfeathering.
4. The *H* terminal serves to drop out relays *LC* and *LD*.

The manual feathering switch is held in the unfeather position long enough for the propeller to return to its normally governed range where the propeller governor is then able to regain control. The automatic feathering circuits have thus been returned to normal and the circuits for each propeller will rearm, provided the engines are at take-off power and the automatic feathering switch is in the on position. Since the automatic feathering circuits have been returned to their normal condition, they will function as previously described. Either propeller will be automatically feathered with further power failure.

It can be seen that the propeller can be unfeathered after completion of the feathering cycle in a like manner.

Manual feathering can be accomplished at any time, provided the propeller of the other engine is not being feathered automatically, by pushing the manual feathering switch to the feather position. Terminal *D* of the manual switch energizes the feathering pump relay, initiating the feathering cycle. Terminal *F* energizes the pickup coil of the *LD* relay, which closes to block the automatic feathering system of the right engine and stop the left-engine fuel-booster pump. Terminal *C* energizes the manual switch holding coil, which holds the switch in the feather position until the ground circuit to the holding coil is broken by the high-pitch cutout switch at the end of the feathering cycle.

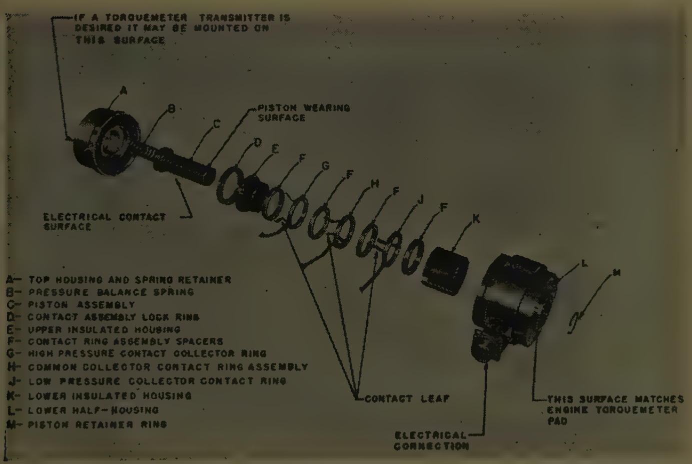

IF A TORQUEMETER TRANSMITTER IS DESIRED IT MAY BE MOUNTED ON THIS SURFACE
A
B
C
PISTON WEARING SURFACE
D
E
F
G
F
H
F
J
F
K
L
M
ELECTRICAL CONTACT SURFACE
A— TOP HOUSING AND SPRING RETAINER
B— PRESSURE BALANCE SPRING
C— PISTON ASSEMBLY
D— CONTACT ASSEMBLY LOCK RING
E— UPPER INSULATED HOUSING
F— CONTACT RING ASSEMBLY SPACERS
G— HIGH PRESSURE CONTACT COLLECTOR RING
H— COMMON COLLECTOR CONTACT RING ASSEMBLY
J— LOW PRESSURE COLLECTOR CONTACT RING
K— LOWER INSULATED HOUSING
L— LOWER HALF-HOUSING
M— PISTON RETAINER RING
CONTACT LEAF
THIS SURFACE MATCHES ENGINE TORQUEMETER PAD
ELECTRICAL CONNECTION

Figure 6. Exploded view, piston-type torque-pressure switch

As is to be expected in the development of any new control system subjected to extreme environmental conditions, failures were experienced during the initial stages of development and testing. Failures of any sort could not be tolerated. A rigorous program of examination and testing of all components was undertaken. Components were redesigned and rebuilt as required, testing rigs suitable for use later in production and service were developed to aid in trouble shooting, and after suitable operation was obtained in flight and on the ground, all components of the system were subjected to environmental requirements well in excess of those expected on the airplane. Within four months after the first circuit was drawn, the first production units had flown 75 hours and had completed hundreds of automatic feathering operations during take-off and in flight at all altitudes up to 6,000 feet.

A standard air dash-pot-type time-delay relay proved adequate, since the limited altitude range within which the automatic feathering system operates has little effect on the timing function of the relay. During the initial testing, a drift in the delay setting was found. This drift was prevented by sealing the time-delay adjustment screw.

Rotary-type relays, with 5-pole double-throw wafer-type contacts, were selected for feathering relays and remembering relays. During the test program it was found that the relays would hold-in on coil voltages as low as 0.5 direct volt. This condition was not tolerable because of the unfeathering operation. The magnetic parts of the rotor of the relay were chrome-plated to raise the drop-out voltage to a minimum of 5 direct volts. To prevent dropout during bus voltage transients, the relays are required to hold-in at 12 direct volts. A standard aircraft-quality double-pole double-throw relay was selected for the arming relay. No trouble has occured in operation.

The complete automatic-feathering relay box, Figure 4, was subjected to a 50-hour vibration test at normal and elevated temperature. While being vibrated at a frequency of 2,500 cycles per minute and a total amplitude of 0.031 inch, the automatic feathering circuits were cycled every two minutes with simulated normal load at the output terminals. The first 40 hours of the test were conducted at room temperature, while the last ten hours were conducted in surroundings of 165 degrees Fahrenheit. The test was done without failure in two days, two hours.

After a careful study of the available pressure switches, the piston-type torque-pressure switch now used was designed. The construction of the piston switch is illustrated in Figure 6. A piston made of an insulating material is balanced between oil at engine torque pressure and a calibrated balance spring. The piston carries a brass bridging contact ring, which makes contact with the common contact leaf at all times, the low-pressure contact leaf below 32 ± 2 pounds per square inch oil pressure, and

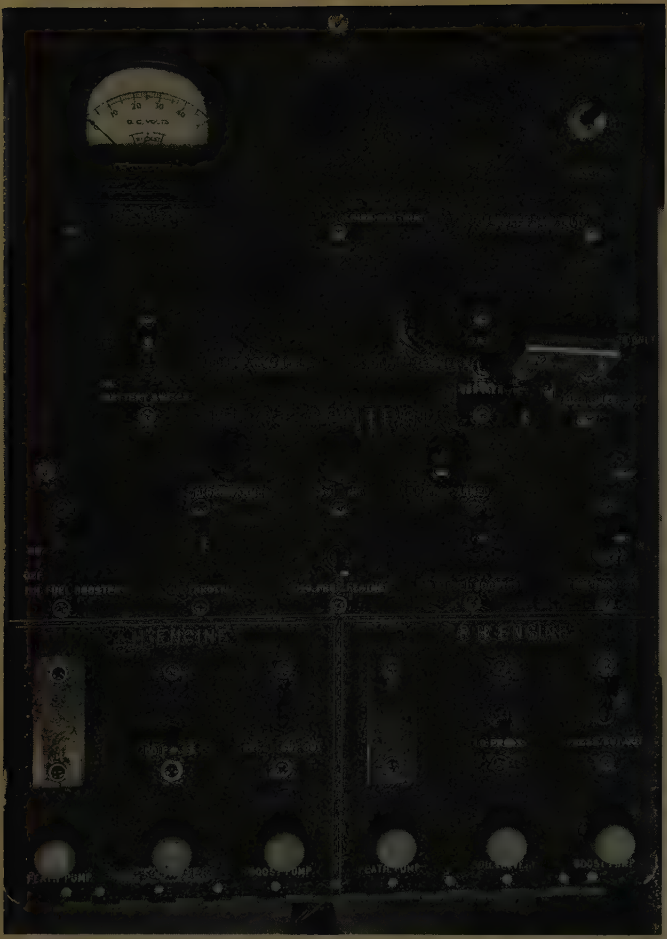


Figure 7. Bench test panel to simulate flight operation of the automatic feathering relay panel

the high-pressure contact leaf above 75 ± 5 pounds per square inch. The piston and spring, the various contact leaves, and the electric connector and wiring are assembled in a split-shell aluminum-alloy housing. The bottom face of the housing fits the standard engine torquemeter pad. The top face is made similar to the engine torquemeter pad for the installation of a torquemeter transmitter if desired. The housing is drilled with suitable oil passages to permit oil flow to and from the piston and the torquemeter pad atop the housing.

The slow-moving sliding contacts of the piston switch are well suited for their required duty. The high-pressure contact closes the circuit to the arming relay coil which draws approximately 0.1 ampere at 28 direct volts. The low-pressure contact closes the time-delay relay coil circuit whenever engine failure occurs during take-off. The time-delay relay coil draws approximately 0.3 ampere at 28 direct volts. After initiating the circuit, the contacts do not carry or break any current.

The piston switch was subjected to a 100-hour vibration test under the same conditions described in the relay control-box test outlined previously. During the 100-hour period, the switch was cycled approximately 9,200 times at normal electric load. The high- and low-pressure settings varied over a maximum range of 2.5 pounds per square inch. No contact pitting or wear was visible after completion of the test. The switch is not affected by vibration or high ambient temperature and exhibits no tendency to chatter.

After soaking at a temperature of −40 degrees Fahrenheit for a period of four hours at a pressure of 80 pounds per square inch, the low-pressure switch contact closed 1.1 seconds after releasing the oil pressure. The results of the test were deemed satisfactory since the test was conducted without the benefit of vibration and it is unlikely that the oil temperature in the torque nose would be as low as that tested after engine warm-up, even in extreme ambient conditions.

During the test program it was found that an improperly bled fluid-type torquemeter transmitter can cause a low-pressure switch closing delay of as long as 15 seconds. The use of an electric transmitter is recommended on aircraft using automatic feathering, if a torquemeter is required.

No change of design of any of the components furnished with the propeller was required. Some minor troubles in the manual feathering equipment, of little consequence when feathering manually, were found during the automatic feathering test program. Hamilton Standard Propeller Division engineers and service representatives gave willingly of their time to isolate and correct the difficulties.

Two complete sets of automatic-feathering system components were built for the initial flight test program. The components were flown alternately, one set of equipment being flight tested while the second set was being reworked or equipped with redesigned parts to eliminate troubles.

To facilitate trouble shooting, a test box was developed for observation of the progress of the feathering cycle in flight. Two groups of indicator lights, one for each propeller, were arranged so that the lights came on in sequence during normal operation of the automatic feathering system. Improper light sequence isolated the source of system trouble. The test box was connected to the circuits to be observed by inserting a short length of cable between the automatic-feathering relay control box disconnect receptacle and the airplane wiring disconnect plug.

Bench test arrangements were built for ground checking all major components of the system before flight. The bench test panel developed to facilitate ground testing of the automatic feathering relay panel later was used as a production test fixture. The test panel, shown in Figure 7, simulated the operation of all other components of the manual and automatic feathering systems.

During the final evaluation program the system was subjected to a cycling test and an accelerated service test. During the cycling test repeated engine failures were simulated in flight. The system successfully completed 100 automatic feather operations in succession in one day's flying. During the accelerated service test, a 75-hour cross-country airplane service performance test without maintenance, engine failures were simulated 11 times.

During the final flight test evaluation and the more than two years of commercial airline service to date, there has been no known instance of the automatic feathering system failing to feather a propeller when such action was indicated or inadvertently feathering the propeller of an engine when such action was not required.

Ignitron Pulse Equipment for Particle Accelerators

C. C. HERSKIND
FELLOW AIEE

J. E. HUDSON

IGNITRON TUBES have been successfully applied as switching elements to supply current pulses to the magnet coil of particle accelerator equipments. Applications involve current pulses having crest amplitudes of 5 to 30 kiloamperes, durations of 1/120 to 1/1,200 second, repetition rates of 6 to 60 per second, and supply voltages up to 20 kv.

Energy for producing the current pulse is stored in a capacitor bank by a charging rectifier. The current pulses are produced by discharging the capacitor bank through the particle-accelerator magnet coil. An ignitron tube is placed in the circuit between magnet coil and capacitor and functions as a switching device to carry the current pulse. Current flow is limited to one-half cycle by the rectifying action of the ignitron and has a duration determined by the inductance and capacity of the circuit. At the end of the current pulse, the capacitor voltage has a polarity opposite to that existing initially and has a magnitude substantially equal to its original value. A reversing circuit is provided which returns the voltage to its original polarity. This may be a second ignitron circuit using either the magnet coil or a separate inductance. A mechanical contactor for reversing capacitor connections may also be used. Before succeeding current pulses occur a charging rectifier raises the capacitor to its original voltage level. An impedance between rectifier and capacitor limits the charging current.

The ignitron contactor assembly consists of the ignitron tubes with their excitation and temperature-regulating equipment. A typical ignitron contactor is shown in Figure 1. The excitation equipment is assembled in a grid box and is mounted with the ignitrons on a common frame which is usually insulated from ground. Insulating power and signal transformers are required for energizing the excitation circuit and controlling tube firing.

Excitation equipment controls the starting of the ignitron tube. To accomplish this satisfactorily, the excitation circuit must provide the following functions:

1. Fire the ignitor and establish a cathode spot on the mercury pool.
2. Supply current to the holding anode to maintain the cathode spot and spread ionization.
3. Start main-anode conduction by applying a positive voltage to the grid of the ignitron tube.
4. Provide a protective circuit for preventing application of positive voltage to the grid when no cathode spot exists on the mercury pool.
5. Provide a negative bias to promote clean-up of ionization and regain grid control after main anode conduction.

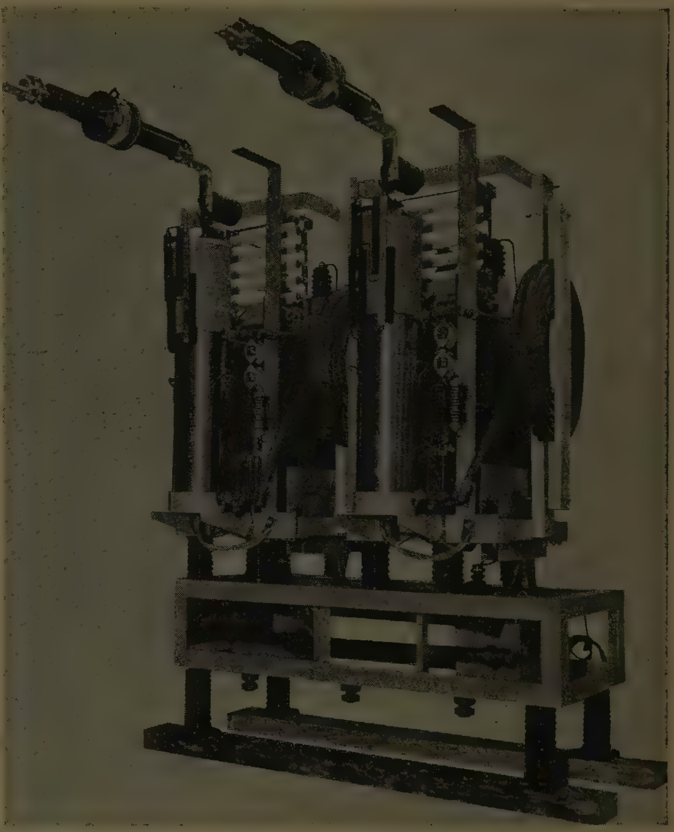


Figure 1. Electronic contactor assembly—view of the ignitron tube and grid boxes taken from the tube side

In particle accelerator operation, the timing of the current pulse is determined by physical processes which may not be accurately synchronized with the power system. The power ignitrons must therefore fire in response to an external signal which is nonsynchronous with respect to the a-c power system. An accurate time relation is also required between the signal and ignitron firing. These requirements rule out the magnetic firing circuit commonly used with ignitrons in rectifier service and necessitate the use of excitation circuits employing vacuum tubes. Arc losses in the ignitron tubes are removed by circulating cooling water in the tube water jackets. The temperature-regulating equipment is like that on power rectifiers, and consists of a heat exchanger, circulating water pump, thermostatically controlled regulating valve, and surge tank.

Data regarding the current capacity, performance, and life of ignitrons in pulse service are limited. Tests show that during high pulse currents the arc drop rises and cathode spots form on the tube side walls. Because of the difficulty and cost of making adequate tests it has not been possible to establish accurately the current level at which such undesirable arc conditions arise and the effect of these conditions upon tube performance and life.

Digest of paper 50-157, "Ignitron Pulse Equipment for Particle Accelerators," recommended by the AIEE Committee on Electric Power Converters and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Combined Phase and Ground Distance Relaying

WARREN C. NEW
ASSOCIATE AIEE

A NEW relaying system provides complete phase- and ground-distance relaying protection for transmission lines. It features a reduction in the necessary equipment usually applied where three relays are connected to protect against faults involving 2- or 3-phase conductors, and where three relays are connected to protect against single-phase-to-ground faults. The reduction in equipment is achieved by causing the directional starting unit of the ground-distance relay to perform the double duty of detecting faults of a phase nature as well as faults of a ground nature.

The complete relaying system for the combined phase and ground protection of 3-phase transmission lines includes three directional-reactance-distance relays, one per phase, for the ground relaying; three reactance relays, one per phase, for the phase relaying; two timing relays, one each for the phase and ground relaying; an auxiliary relay for blocking the ground trip circuits on all faults except single-phase-to-ground faults; and an auxiliary current transformer.

The auxiliary current transformer is used to compensate the phase quantities supplied to the relay by adding portions of the residual currents of the protected line and of any nearby or parallel lines. This type of current compensation offers the advantage of a higher torque relay since the applied potential restraint is the full line to neutral voltage. Figure 1 shows schematically how these quantities are supplied to the relays.

In this relaying scheme a unit must be provided to determine that fault conditions actually exist and then to determine if the fault is in the tripping direction. This is done by the directional-impedance starting unit of the basic reactance-distance relay. The starting unit causes tripping in third-zone time for all types of faults which may occur.

Once the fault condition is verified a unit must be provided to measure the distance to that fault to determine whether or not the fault lies within the instantaneous or time tripping zones. This is performed by the ohm units, which are reactance-measuring units.

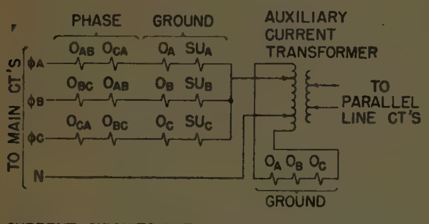
Each ground ohm unit is supplied with a phase current in one current winding and the compensating current from the auxiliary current transformer in the other current winding. The phase ohm units are supplied with two phase currents, one in each current winding. Both ohm units are supplied with adjustable voltage restraint; phase-to-neutral voltage is supplied to the ground ohm units, and phase-to-phase voltage is supplied to the phase ohm units.

The ohm units are each provided with a transfer relay to provide the second zone of protection.

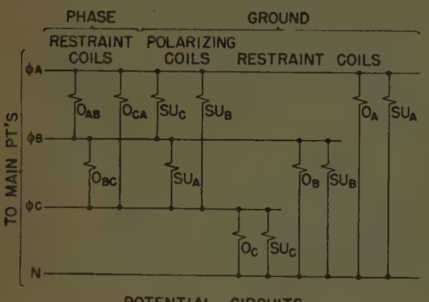
Referring to the connection diagram, Figure 2, the sequence of operation of the contact circuits may be explained. A single-phase-to-ground fault on phase *A* will operate the starting unit *SU* which in turn will operate the auxiliary blocking relay A_A and start the timing units TU_G and $TU\phi$ through their auxiliary relays TX_G and $TX\phi$. The trip circuit for phase *A* will then be complete to the ground-ohm-unit contacts O_G. If the fault is within the first zone of reach of the ground-ohm unit, that unit will operate and trip the circuit breaker through the first-zone ground targets T_{1G}.

If the fault is beyond the reach of the first zone after the timer TU_G has operated its number 2 contact, the ohm-unit transfer auxiliary OX_G will operate and change the ohm-unit calibration by applying a smaller potential restraint. If the fault lies within the second zone of reach, the ohm unit will operate and trip the circuit breaker through the second-zone ground target T_{2G}. If the fault is beyond the second-zone reach, when the timer TU_G has operated its number 3 contact, the circuit breaker will be tripped by the starting-unit contact *SU* through the third-zone target T_3.

Phase ohm units operate like ground ohm units, since they work in conjunction with a separate auxiliary transfer relay $OX\phi$ and separate timer $TU\phi$, but the a-c connections of the phase-ohm-units allow them to operate on different line quantities.


PHASE
GROUND
AUXILIARY CURRENT TRANSFORMER
TO MAIN CT'S
ϕA
ϕB
ϕC
N
O_{AB} O_{CA} O_A SU_A
O_{BC} O_{AB} O_B SU_B
O_{CA} O_{BC} O_C SU_C
TO PARALLEL LINE CT'S
O_A O_B O_C
GROUND

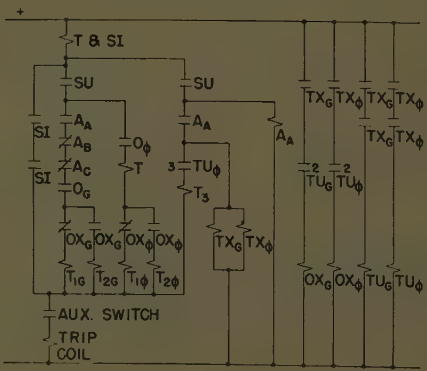
CURRENT CIRCUITS WITH CURRENT COMPENSATION



POTENTIAL CIRCUITS

Figure 1 (left). Current and potential connections to the relay

Figure 2 (right, below). Circuit-breaker control circuits for phase A



Digest of paper 50-7, "Combined Phase and Ground Distance Relaying," approved by the AIEE Committee on Relays and recommended by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Influence of Electrodes on D-C Breakdown in Gases at High Pressure

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D-c breakdown measurements up to 900 kv between metallic electrodes producing a uniform field and immersed in compressed gases show markedly higher values for stainless steel after conditioning by sparkover than for aluminum electrode systems. Sparkover voltage measurements were made in air, in carbon dioxide, in equal mixtures of carbon dioxide and nitrogen, and in nitrogen. The relative insulating strength of these gases diminished in the order listed, and a similar electrode dependence on higher pressure was shown in all of them.

THE INVESTIGATION of the influence of electrodes on breakdown in gases was prompted by the steadily increasing importance of gases at high pressure as the principal insulating medium for high-voltage apparatus. Particularly for Van de Graaff electrostatic generators and other direct forms of particle accelerators compressed-gas insulation has become essential to the attainment of high-energy particles in a compact and economic design.[1] It is likely that high-pressure gas insulation will gradually invade the realm of high-power engineering where high-voltage cables and transformers are the most obvious immediate applications.

In this study the d-c breakdown strength in the gap between metallic electrodes shaped to produce a uniform electric field was determined for a variety of gases over a pressure range from atmospheric to 400 pounds per square inch gauge. In the course of this work a marked difference between the breakdown strength of aluminum and of stainless-steel electrodes at the higher pressures was observed, and this important fact became a particular point of inquiry. Measurements were made in air, in carbon dioxide, in nitrogen, and in equal mixtures of nitrogen and carbon dioxide, using electrostatically generated constant voltages up to 900 kv.

The voltage source was a Van de Graaff test generator with a 12-inch-diameter terminal contained in an 18-inch-diameter steel pressure tank. At the higher pressures in air this apparatus is capable of producing steady voltages of over 1,000 kv. The voltage of the terminal was continuously measured by a generating voltmeter[2] with an estimated absolute accuracy of ±1 per cent.

In all cases the electrodes between which breakdown took place were shaped with the Rogowski[3] contour to secure an essentially uniform and maximum electric field in the central area of the gap. Their maximum diameter was six inches. Both the aluminum electrodes of *2S* grade and the *304* stainless-steel electrodes were carefully machined, smoothed with successively finer emery, and finally buffed to a mirror finish. The interelectrode gap could be adjusted by moving the upper electrode through an insulated screw-thread arrangement in the upper tank cover. The lower electrode was fixed to the high-voltage terminal of the generator. Only relatively high prebreakdown currents to the upper terminal were regularly measured, using a 0- to 20-microampere d-c ammeter.

The test gases were introduced into the main pressure vessel and served also as the insulating medium of the electrostatic generator. Since the selected electrode gaps were one-fourth inch, one-half inch, and three-fourths inch, the limitation in voltage in this system was always clearly defined by the gap itself. The generator tank was dried by evacuation overnight with dry ice in the vacuum line. Air and commercial nitrogen and carbon dioxide passed through dry silica gel insured a thoroughly dry gas system.

Sparkover voltage measurements continue to suffer from the arbitrary determination on the part of each experimenter of a workable sparkover criterion and from the relatively wide variations in the reported results due both to the complex nature of the discharge and to the importance of experimental factors. Even the selection of a specific average rate of sparking was found to be dependent on the direction in and rapidity with which the final value was approached. Influential factors include the size and shape of the electrodes, the smoothness and polish of the surfaces, and especially the amount and kind of electrical conditioning used.

In order to secure stable testing conditions, it was found desirable to condition the electrodes by permitting limited sparkover at the highest gas pressure and with the 3/4-inch gap. For the stainless-steel electrodes this had the effect of gradually increasing the voltage which could be insulated, presumably because of the clean-up action of the discharges on the contamination of the electrode surface. The final voltages were usually about 50 per cent higher than the initial sparkover values and were attained after several hundred sparks. The aluminum electrodes showed relatively less improvement and reached their limiting voltage more rapidly under conditioning by sparkover. The performance of the aluminum electrodes often could be impaired by permitting continued sparkover at the higher

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voltages and pressures. This work confirmed some of the observations of Howell[4] and others that in the case of steel electrodes the ultimate sparkover voltage could be improved by conditioning with limited energy in the discharge and that the required amount of conditioning became less the more highly finished and highly polished the electrode surface was.

With conditioning completed, the voltage-breakdown measurements were made by raising the gap voltage in steps of about five per cent of the expected breakdown value. Each succeeding voltage level was held for three minutes until one or two sparks were obtained on the average in the 3-minute interval. This arbitrary criterion established the limiting voltage value for that gap. It was found that at pressures below about 100 pounds per square inch the sparkover voltage was more clearly defined and could be approached more rapidly. At least three independent sets of data were taken for each pressure and each gap in order to demonstrate the variations which might be expected in this phenomenon.

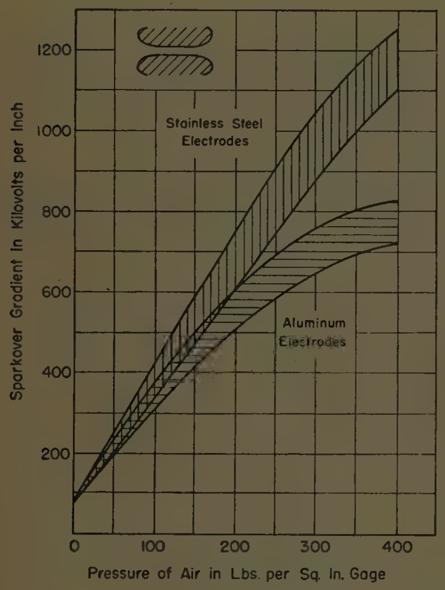


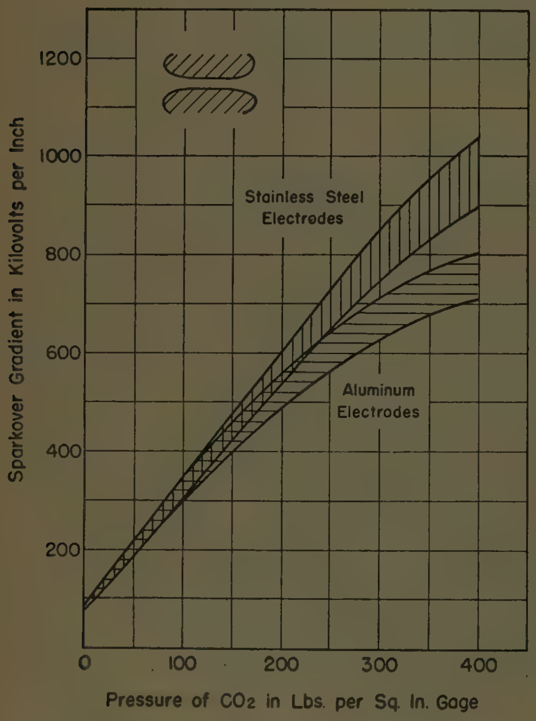
Figure 1. Insulating strength in compressed air with stainless-steel and with aluminum electrodes producing uniform fields over 1/4-, 1/2-, and 3/4-inch gaps

COMPARISON OF STAINLESS STEEL AND ALUMINUM ELECTRODES

Figure 1 compares the d-c breakdown strength of uniform electric fields in compressed air between stainless-steel electrodes with that for aluminum electrodes. While substantially the same insulating strength is realized at pressures below 100 pounds per square inch gauge, the stainless-steel electrode system exhibits progressively superior performance with higher pressures. At 400 pounds per square inch about 50 per cent higher voltages could be insulated with stainless steel than with aluminum. Figures 2, 3, and 4 show the d-c breakdown strength for stainless-steel and aluminum electrodes in carbon dioxide, an equal mixture of nitrogen and carbon dioxide, and nitrogen. These curves incorporate the breakdown values for the several gaps which were studied, including 1/4-, 1/2-, and 3/4-inch lengths.

No dependence of any breakdown strength upon gap length or total voltage was observed, the breakdown gradient for the several gaps being a constant at a given gas pressure within the limits of experimental error. The shaded area of each curve indicates the observed divergence in the breakdown values during the several experimental runs. Because of the complex and statistical character of the breakdown phenomenon, as well as its dependence upon local electrode geometry, surface contamination, and the degree of electrical conditioning, such divergence is recognized as an almost inevitable part of voltage breakdown in gases.

In comparing these curves, it should be remembered that, although the aluminum electrode systems received less conditioning by controlled sparkover than those of stainless



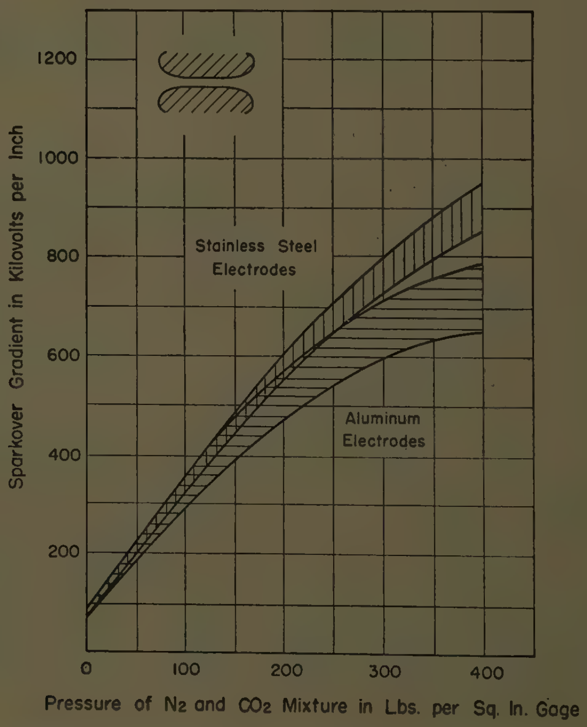


Figure 2 (left). Insulating strength in compressed CO_2 with stainless-steel and with aluminum electrodes

Figure 3 (right). Insulating strength in equal compressed mixtures of N_2 and CO_2 with stainless-steel and with aluminum electrodes

steel, this process was in both cases carried to the extent required for maximum performance. Only in the case of nitrogen gas with aluminum electrodes did the prebreakdown current consistently show values in excess of two microamperes. It can be observed that the same dependence of breakdown strength upon electrode materials exists for these several gases, that the superiority of stainless steel is most marked in the case of air, and that at pressures above ten atmospheres and for systems that can be electrically conditioned it appears advantageous to use stainless steel in preference to aluminum because of the substantial improvement in voltage insulating strength.

INFLUENCE OF CATHODE AND ANODE ELECTRODE MATERIAL

FIGURE 5 shows the variation of d-c sparkover voltage with pressure for a uniform field in air as a function of the cathode and anode material. The upper and lower curves represent the average of the d-c sparkover characteristics shown in Figure 1 for all-stainless and all-aluminum electrode systems. The intermediate curves show the marked reduction of insulating strength resulting from a mixed gap of one aluminum and one stainless-steel electrode. This reduction was greatest when the cathode was aluminum and resulted in a sparkover characteristic close to, though generally slightly better than, that of an all-aluminum gap. With a stainless-steel cathode and an aluminum anode the sparkover pattern at lower pressures approached the performance of all stainless steel, but deteriorated at higher pressures.

Since it would be expected that the cathode would be of determining importance, several confirming check tests on this observation were made using freshly polished electrodes. Evidence[5] recently has been presented which states that the anode material is without influence on the breakdown potential of a mixed gap at high pressure in which only small predischarge currents are permitted to flow. In any gap-testing procedure involving sparking, the cathode emission characteristics may be modified by sputtered or evaporated anode metal. It is also very possible that the emission characteristics of the anode material could produce observable effects on both predischarge currents and the sparkover criterion.

In any event, although the cathode emission characteristics are believed to be the primary factor, it seems clear that in any practical measurement involving sparkover, the insulating characteristic at high gas pressures of the interelectrode gap can also be significantly affected by the use of an inferior electrode material on the anode.

The relative insulating strength of uniform gaps between stainless-steel electrodes and between aluminum electrodes may be examined as a function of gas pressure as in Figure 6 or as a function of the gradient on the more limited electrode as in Figure 7. The insulating strength of a pressure gap is dependent on the α, β, and γ mechanisms developing primarily in the interelectrode space. The effect of higher pressures, by reducing the probability of these gaseous ionization processes, is to permit the application of progressively higher gradients to the electrode surfaces, which may then become the principal limitation. From Figure 6 it can be seen that the ratio of maximum gradients for the two metals increases steadily with pressure, that this ratio is different for the several gases and roughly proportionate to their relative insulating strength. Figure 7 shows more clearly that the limiting influence in the insulating strength of the gap is determined primarily by the electrode gradient. The increasingly upward slope of these curves suggests that a surface gradient is gradually being reached at which the most limited (aluminum) electrode is contributing exponentially to the sparkover of the gap. This contribution must come primarily from the cathode surface and consist of photoelectric, secondary, and high field emission. High field emission must be regarded as a probable mechanism even at gradients of 500 kv per inch since this average value is increased by localized projections and since the surface is

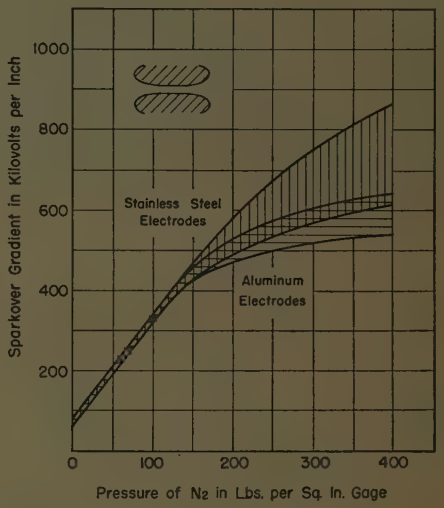


Figure 4. Insulating strength in compressed N_2 with stainless-steel and with aluminum electrodes producing uniform fields over 1/4-, 1/2-, and 3/4-inch gaps

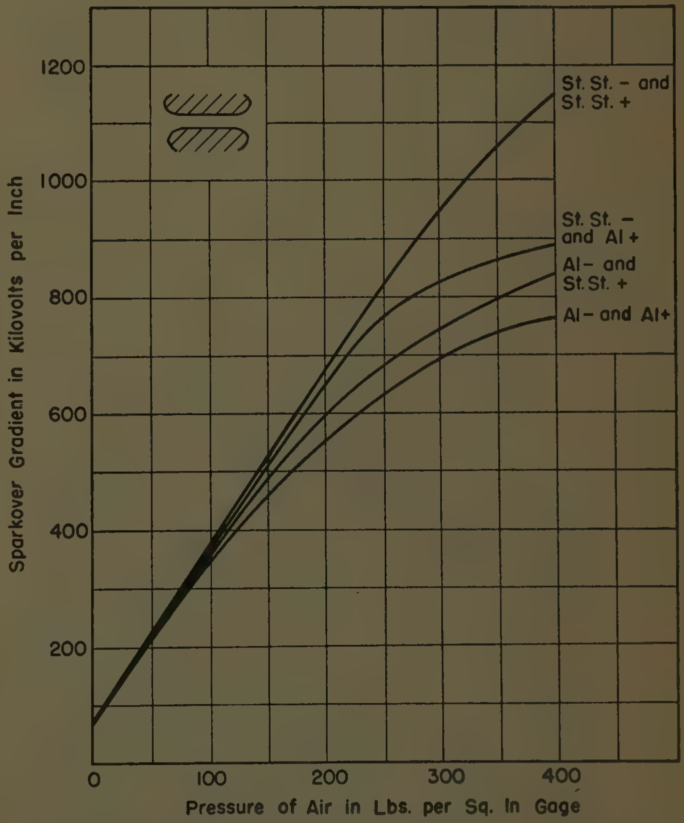


Figure 5. Insulating strength in compressed air between electrodes of similar and dissimilar materials

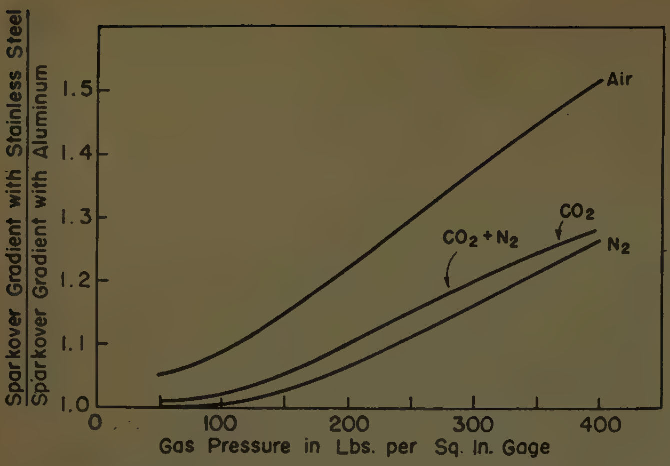


Figure 6. Ratio of sparkover gradients on stainless-steel and on aluminum electrodes as a function of gas pressure

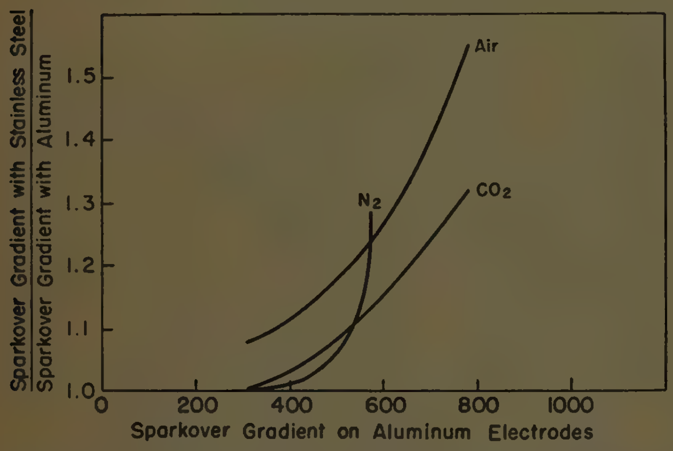


Figure 7. Ratio of sparkover gradients on stainless-steel and on aluminum electrodes as a function of gradient on the aluminum electrode

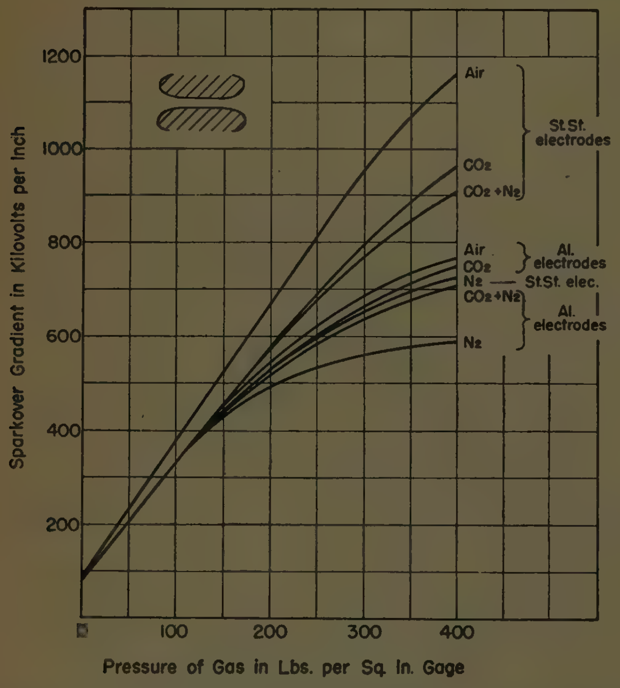


Figure 8. Comparative insulating strength of several gases at high pressures for uniform fields between stainless-steel electrodes and between aluminum electrodes

necessarily contaminated by relatively low-work-function material.

These fields may also serve to enhance secondary and photoelectric emission to many times their ordinary value.[6] While the nature and number of gas molecules in the interelectrode space continue to affect the sparkover criterion, it appears that the nature of the electrode surface, particularly the emission coefficients of the surface of the cathode, become the controlling factors at the higher voltage gradients.

PERFORMANCE IN OTHER GASES

A comparison of the d-c sparkover strength in several gases for stainless-steel-electrode and for aluminum-electrode systems over a pressure range up to 400 pounds per square inch is made in Figure 8. In addition to the marked superiority at higher pressures of the stainless-steel-electrode systems, these curves show that the highest insulating strength is obtained in air and progressively lower strengths are realized in carbon dioxide, in an equal mixture of carbon dioxide and nitrogen, and in nitrogen—in the order in which they are named.

The observation of the superiority of air over the other permanent gases has often been confirmed in studies with pressurized Van de Graaff accelerators. The advantage of nitrogen and carbon dioxide lies mainly in their chemical inertness, and it is believed that for most general applications where a fire hazard exists a mixture of carbon dioxide and nitrogen is desirable. Other studies have indicated little difference in the performance of Van de Graaff generators operating at a given total pressure for mixtures in which the carbon-dioxide content was varied from 20 to 80 per cent.

It is very probable that the influence of carbon dioxide in improving the insulating strength of a given electrode system is due primarily to the electronegative character of the oxygen atoms, although minor benefits are probably obtained because of the larger collision cross section of this molecule. This study has not concerned itself with certain halogen compounds, such as Freon 12 (CCl_2F_2) and sulfur hexafluoride (SF_6), which are known to be distinctly superior to air at a given pressure, but which may have limitations where continuous ionization and sparkover would ultimately result in their chemical decomposition and consequent failure.[7]

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A 5,000-Kva Underground Substation

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BECAUSE large increases in electrical usage in the downtown area of San Diego, Calif., began overtaxing the primary radial feeders of the San Diego Gas and Electric Company, it was decided to establish an entirely new substation to feed the area, taking advantage of existing 12-kv tie lines near by. The primary radial feeders were feeding a portion of the area from already heavily loaded substations and a new substation seemed to be a better solution to the problem than to increase facilities in the existing substations, where space was limited, and recopper lengthy radial feeders or install new ones.

Because of the high cost of real estate in the central part of the city, it was estimated that an underground substation would be the most economical installation, especially if a ready-made vault with adequate ventilation could be obtained.

As no ready-made space was available, it was decided to dig a vault under the floor of the San Diego Gas and Electric Company's garage, which was fortunately located within a block of the area to be served. The vault had to be excavated in such a way as to take advantage of an existing building incinerator flue. Fans were installed to draw air at 300 cubic feet per second from the office building basement and exhaust it up the flue, serving the double purpose of cooling the transformers and keeping the air in the basement fresh.

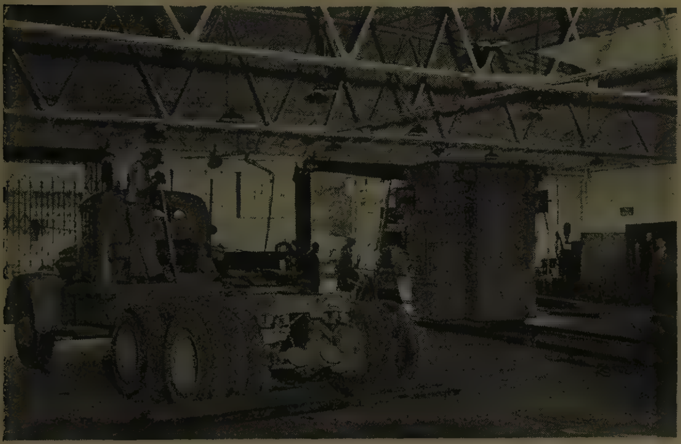

Figure 1. Skidding the main power transformer along the garage floor

Some difficulty was enccuntered in constructing the vault and installing the equipment because of the limited clearances in the garage itself and because it was imperative that the garage be kept available for use during construction. Because the roof trusses were only 12 feet above the garage floor, it was necessary to dig the main vault, 45 by 23 by 16 feet, with a small "Hoe-back." The dirt was dumped on the garage floor from which it was lifted into waiting trucks by a pneumatic-tired "High-lift."

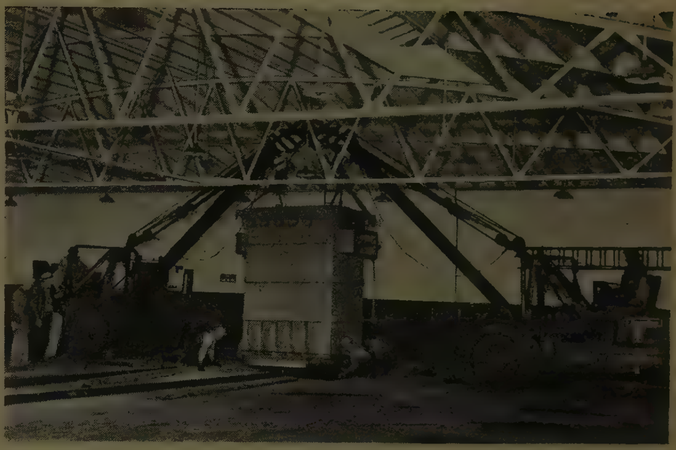

Figure 2. Main power transformer ready to be lowered into the vault

The main transformer, weighing 35,000 pounds, was skidded into the garage on greased angle irons, see Figure 1, as it was impossible to get it through the garage door any other way. The transformer is 11 feet $1^5/_8$ inches high, and the garage door lintel is 11 feet $2^3/_4$ inches high at the lowest point. By bolting the booms of two Krane-Kars together above the center of the transformer and running cables between their axles, it was possible to lower the heavy unit through the opening into the vault, see Figure 2, removing 12 by 12 cribbing as the lowering progressed.

The substation proper is of the conventional metal-clad type, consisting of two incoming 12-kv feeders operating in parallel and protected by pilot-wire relaying. They feed a 5,000/6,667-kva 3-phase 12/4.16-kv tap-changing-under-load transformer with $\pm 7^1/_2$-per cent automatic tap changing. There are three outgoing 4-kv feeders and a 4-kv transfer feeder and bus. All circuit breakers are solenoid-operated air circuit breakers, and the substation has full supervisory control.

Facilities are provided for the removal of equipment and for the connection of a 12/4-kv mobile substation in the event of station transformer failure. The mobile substation can be parked in the garage above the vault. In addition to the conventional alarms, equipment is included which will automatically shut down the air supply to the vault in the event of a fire. Also, provisions for flooding the vault with carbon dioxide brought from an outside source have been made.

Operation of the substation has been very satisfactory, with transformer temperatures under peak loads remaining well within allowable limits.

Digest of paper 50-142, "A 5,000-Kva Underground Substation," recommended by the AIEE Committee on Substations and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Centralized Control of Steam-Electric Generators

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CENTRALIZED control of steam-electric generating units has been a natural and gradual evolution over the years. It has been accelerated by such factors as development of suitable equipment and controls, creation of new plant heat cycles, and rapid growth in the size of the units and of the electrical utility industry. The authors believe that current controversies over centralization of controls are concerned primarily with what shall be included and how centralization is to be accomplished and not so much with the basic idea of centralization.

In early steam-electric generating stations the boiler room personnel operated as a separate department because the many small boilers employed necessitated a large staff. Steam interconnections obviated the need to co-ordinate any group of boilers with specific turbines. At the same time the electrical operators were concerned with matters other than the generators, such as local feeders, tie lines, and street lighting. Consequently, an over-all plant control scheme developed whereby the electrical group became divorced from the mechanical group, and the mechanical group further divided into a turbine room group and a boiler room group. This division of responsibility did not foster co-operation because understanding of each other's problems was lacking.

These conditions laid the groundwork for improvement. Addition of a steam-header pressure gauge in the electric control room permitted load swings at such rate as the boiler room could take at that moment. A station load indicator in the boiler room informed boiler operators of the load trend. Further co-ordination was attained by use of intercommunication facilities.

When Oswego Steam Station was being designed in the late 1930's, a unit system was decided upon consisting of a boiler, turbine, and generator. No steam, feedwater, or electric interconnections at generator voltage were provided. The controls for such a station required an entirely new approach and presented an opportunity for major improvement.

A conception, believed to be original, was that of a "straight line" organization for each unit, originating with a "unit operator" who would be in a position to supervise all operations of one boiler-turbine-generator unit. Normally, he would control generation to suit load, but he would also limit generation to the capability of the unit and its associated equipment. In working out the details, the control centers for two units were consolidated in a central control room.

The electric control board contains the usual switchboard controls and meters with frequency and tie-line loading controls in the central section and the electric controls for one unit on either side. The mechanical control board for each unit is at right angles to the electric board. From boiler to turbine-generator ends, it contains pulverizer and burner controls, combustion and steam pressure controls, control of condensate and feedwater from condenser to boiler, and finally controls for the turbine and its auxiliaries at the turbine room end. It has been the purpose to centralize on these panels all of those functions which require adjustment for safe and dependable operation over the normal load range of each machine which, in the case of Oswego, represents a load range from about 10 to 100 megawatts. For simplicity, functions related principally to start-up and common facilities which operate on a plant-wide basis have been omitted from the control room.

The value of closely co-ordinated operation of a unit by means of centralized control is illustrated in nearly every operating abnormality. For example, on failure of coal to mills, the electrical operator is immediately alerted to stand by and drop generation if necessary to maintain steam pressure. The sacrifice of a few megawatts for a few minutes can sometimes avoid serious trouble, and load drops might even be greater due to efficiency loss if steam pressure decreased.

When operating on block loads and the load supervisor calls for a change, the switchboard operator announces what is to be done as he steps to the panel. The mechanical man will advise him if there is reason to make the change in any manner different from normal. If a quick change is required, the rate of change is determined by ability to maintain water level, steam pressure, draft, or whatever may be most critical at that moment. If electrical trouble occurs, the boiler operator likewise knows at once the nature of changes necessary to restore order.

A new station, identical to Oswego in arrangement, is now under construction and similar centralized control will be incorporated. The units comprising the initial installation will be of the reheat type. Study of the operation of such units indicates a greater need for co-ordination between boiler, turbine, and generator controls than is the case with straight through machines. Centralized control is an ideal way of accomplishing this.

The desirability of centralized controls in generating stations of the independent unit type of design has been confirmed by nearly ten years of experience with two units at Oswego. Observations at Oswego and independent studies have demonstrated their advantages to a different operating group which is experienced with separate electric control rooms. Even greater benefits can be foreseen when centralization is applied to the new, more complicated heat cycles.

Digest of paper 50-187, "Centralized Control Desirable for Single Boiler Turbine-Generator Units," recommended by the AIEE Committee on Power Generation and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Differential Relay Sensitivity Adjuster

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MEMBER AIEE

MAGNETIZING INRUSH CURRENT experienced when energizing a transformer has always presented a problem in the application of differential relays. The inrush current appears to the differential relay as a fault within the transformer and will cause the relay to operate and trip the transformer circuit breakers incorrectly. This problem is increased with the use of large transformers.

To overcome this difficulty, a device has been developed which automatically desensitizes the differential relay during the inrush period. This device is referred to as a sensitivity adjuster and consists of a small iron-core reactor connected across the restraint winding terminals of the differential relay. A center tap on the reactor winding is connected to the operating winding terminal of the differential relay by a circuit which includes the contacts of a time-delay relay and may also include an adjustable resistor. The sensitivity adjuster is a simple device and can be applied to almost any type of percentage restraint differential relay. The adjuster does not change the sensitivity of the differential relay or interfere in any way with the relay operation during normal conditions.

One adjuster is required for each phase element of the differential relay and can be easily applied, even on relays that are already in service. The application of this device does not require making any changes in the differential relay or its adjustment. The setting required for the differential relay during the inrush period is determined primarily by the number of turns on the reactor. A low-ohmage adjustable resistor in series with the center tap of the reactor can be used if further accuracy is required.

Figure 1 shows a sensitivity adjuster applied to one phase element of a differential relay. When the transformer is de-energized, relay *C* is de-energized and contact *C′* is closed. So long as contact *C′* is closed, the differential relay setting is desensitized to prevent operation on magnetizing inrush. When the transformer is energized, relay *C* is energized which after a time delay opens contact *C′* restoring the differential relay to a normal sensitive setting. If a fault of sufficient magnitude occurs in the transformer during the inrush period, it will be detected by the differential relay which will operate to clear the transformer from the system.

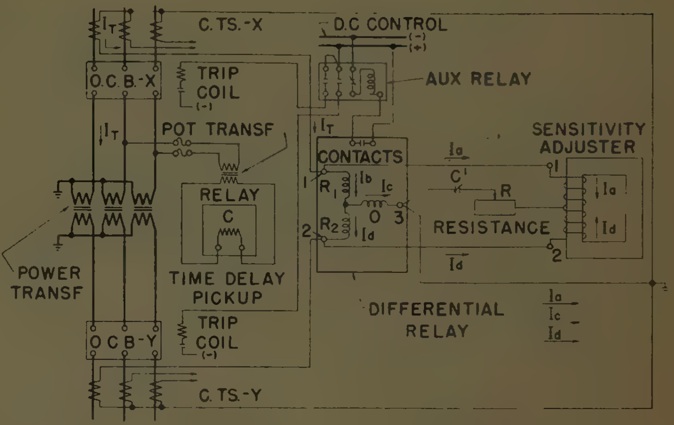

Figure 1. Percentage differential relay equipped with sensitivity adjuster

Table I. Tests Without Sensitivity Adjuster

Test Number	Magnetizing Inrush, 33 Kilovolt-Amperes, rms			Relay Response
	Phase *A*	Phase *B*	Phase *C*	
1	700	1,160	360	Phase *B*
2	1,200	500	500	Phase *A*
3	1,200	1,200	700	Phase *A* and Phase *B*

Table II. Tests With Sensitivity Adjuster Connected

Test Number	Magnetizing Inrush 33 Kilovolt-Amperes, rms			Relay Response
	Phase *A*	Phase *B*	Phase *C*	
4	350	340	860	None
5	400	1,140	620	None
6	1,200	540	1,200	None
7	700	1,160	400	None
8	1,150	500	400	None

Tests were made to determine the effect of magnetizing inrush current on a differential relay equipped with a sensitivity adjuster. These tests were made on a 40,000-kva 33/110-kv 3-phase transformer by energizing the transformer through a 33-kv oil circuit breaker. The transformer was equipped with percentage restraint differential relays set for sensitive operation to give maximum protection.

The first series of tests was made by energizing the transformer several times with the sensitivity adjuster disconnected from the differential relay. Each time the transformer was energized the inrush current was sufficient to cause the differential relay to operate. The second series of tests was made with the sensitivity adjuster connected to the differential relay. No change was made in the normal setting of the relay. The transformer was again energized several times, and each time the inrush current was equally severe as on the previous tests. However, the differential relay did not respond to trip the transformer circuit breakers. The results of these tests are shown in Tables I and II.

The use of sensitivity adjusters on transformer differential relays prevents the relays from tripping on magnetizing inrush and permits extremely sensitive relay settings.

Digest of paper 50-190, "Differential Relay Sensitivity Adjuster," recommended by the AIEE Committee on Relays and approved by the AIEE Technical Program Committee for presentation at the AIEE Middle Eastern District Meeting, Baltimore, Md., October 3–5, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Low Noise and Distortion Audio Multiplexing Equipment With High Stability Carrier

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This article describes a frequency-division multiplexing system used with a 30-kc audio spectrum offered by the Type-FB microwave radio equipment. The system described is especially suitable for providing telephone, telemetering, load-frequency control, supervisory control, and similar communication circuits over distances up to about 50 miles.

THE EQUIPMENT DESCRIBED in this article was the result of conclusions reached while contemplating the problem of how best to utilize the 30-kc "Audio" spectrum offered by the Type-*FB* microwave radio equipment. The market for the radio equipment primarily was to be in the electrical utility field. It was proposed as especially suitable for providing telephone, telemetering, load-frequency control, supervisory control, and similar communication circuits over distances up to about 50 miles. It was recognized that with microwave radio, the terrain would be a control factor in the maximum length of a radio circuit without repeater stations. A need exists for a communication facility of multicircuit capacity for such distances, both because of the growing congestion of the power-line carrier frequency spectrum and because of the increasing difficulty of applying carrier to the shorter power lines.

The two fundamental methods of multiplexing a given communication circuit are frequency division and time division. Frequency division permits all circuits derived by this means to function simultaneously. The useful frequency range of the communication circuit which is to be multiplexed is divided into several frequency bands, each wide enough for handling the function or functions required of it. For telephone service the usual bandwidth is about 2,500 cycles (from 250 to 2,750 cycles) and for a telegraph service the bandwidth required is a function of the repetition rate of the pulses and the maximum rise time (steepness of wave front and trailing edges) that can be tolerated by the service. Practically all of the common telegraphic services can be handled in a 120-cycle bandwidth.

Since it is not practical to adjust the frequencies of the voices of several people who might want to talk simultaneously over a multiplexed circuit without mutual interference, it becomes necessary to translate the signals of every voice but one to different parts of the spectrum of the circuit. By the use of well-known methods, several different carrier frequencies are used with individual provisions for modulation, each being assigned to handle one voice circuit. The carrier frequencies are spaced to provide a bandwidth of about 2,500 cycles for the voice signals plus an additional amount to allow for imperfections of one kind or another in the equipment, such as band-pass filters which cannot be made to have perfectly rectangular attenuation characteristics. Any form of modulation may be used on the multiplexing carriers, and its choice will either dictate the maximum number of voice circuits which can be derived from the common circuit, or it will be limited by a requirement imposed on the designer to produce from the common circuit a maximum number of derived voice circuits.

Having produced a system deriving several circuits from a common one, each of which has a bandwidth of about 2,500 cycles, it follows that the previously mentioned telegraphic services, individually requiring much smaller bandwidths, could be applied to such a voice circuit so long as the telegraph-circuit signal frequencies were confined to the voice-frequency band, 250 to approximately 2,750 cycles per second.

Figure 1 illustrates the application of frequency-division multiplexing principles to a wire or radio circuit having essentially a flat frequency response from 0 to 30,000 cycles. It is based upon the use of amplitude modulation of the carrier frequencies, with the carrier frequencies suppressed and band-pass filters used to permit transmission of the lower sideband only. Carrier frequency assignments are indicated by dotted lines with arrowheads. The associated lower sideband is indicated by a box to its left containing a number which identifies the circuit so derived. Circuit *1*, it is seen, has no associated carrier frequency assignment; it needs none because it is applied directly to the wire or radio circuit without translation.

The second method, time-division multiplexing, involves only one basic difference from the frequency-division system in deriving the desired circuits (see Figure 2). It transmits over the radio or wire facility only one message at a time. A period of time called the repetition or sampling rate, which is short with reference to the highest frequency present in the voice or signal circuits, is divided into a number of parts, usually equal to one more than the number of signal circuits to be applied to the radio circuit. During a relatively small portion of each such part a connection is electronically made to each of the signal circuits

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Essentially full text of paper 50-162, "A Low Noise and Distortion Audio Multiplexing Equipment With High Stability Carrier Supply," recommended by the AIEE Committee on Carrier Currents and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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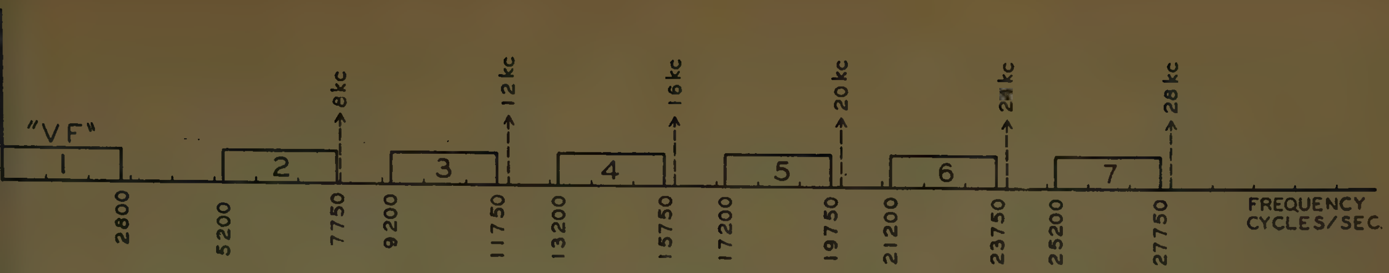


Figure 1. Carrier frequency assignments, spacings, and voice circuit bandwidths for a typical frequency-division multiplexing system which will provide reasonably complete utilization of a nominal 30-kc common circuit, whether wire or radio

in turn, until all have been sampled. Each sample is used to alter some distinctive characteristic, such as amplitude or position relative to an index position of a pulse produced by a local pulse generator. Basically these pulses occur at the repetition rate and are delivered to the modulating equipment where the signal samples modify them. These modulated pulses then are used to modulate the radio carrier, and at the receiving terminal the pulses are sorted out and delivered to their proper demodulators. The outputs of these demodulators are samples of the original signal voltages, which are passed through a low-pass filter, and then delivered to their respective extension circuits.

The radio equipment to be multiplexed offered an audio band of about 200 to 30,000 cycles. Due to the choice of seven derived circuits as a maximum, and a 2,500-cycle bandwidth, frequency-division multiplexing appeared to be the logical selection and is the system which will be described. To be reasonably economical in the use of the 30-kc spectrum, the modulation system selected was amplitude, single sideband, with the multiplexing carriers suppressed in balanced-bridge circuits. The desired sidebands are selected by the use of band-pass filters having cutoff characteristics giving signal-to-noise ratios better than 50 decibels in all multiplexed circuits. This system has been designed to provide a maximum of six multiplexed circuits, each with a bandwidth of 250 to 2,800 cycles. In addition, of course, the radio can be modulated directly from a seventh circuit, and the bandwidth in this case is 200 to 2,800 cycles.

The signals applied to the multiplexing equipment by the connected telephone lines amplitude-modulate the multiplexing carrier frequencies in ring-modulator circuits. Copper-oxide rectifiers are the nonlinear elements in this circuit. The panels containing these circuits are called frequency translator panels, or translators. Figure 3 shows a block diagram of the electrical arrangement of the translator panel constructed to provide three derived circuits. The translators have insertion losses and, therefore, when combined into a complete system represented by the block diagram of Figure 4, amplification of the translator output is provided by an amplifier indicated by the triangular symbol enclosing the initials *HF*.

The amplifier unit amplifies the output of all the sending translator circuits. It must not only have a flat amplitude response from at least 5 kc to 30 kc, but it also must have extremely low intermodulation distortion to prevent causing crosstalk between the several signal circuits as they are amplified in this common unit. The unit is a 2-stage push-pull amplifier with some feedback, having transformers in the input and output circuits and resistance–capacitance coupling. Two *6SN7* tubes are so used that if one tube fails the other will continue to provide a working amplifier on a single-ended 2-stage basis. Under such conditions the gain will be reduced, and the distortion will increase, but the multiplexed circuits will be maintained. The circuit of Figure 4 provided the three telephone circuits as three derived circuits, and the voice-frequency circuit was used for telegraphic circuits by applying suitable tone equipment.

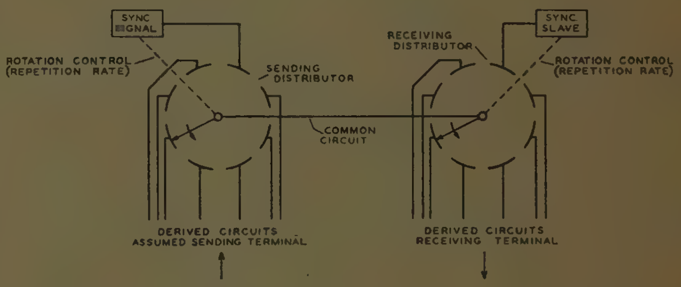

SYNC SIGNAL
ROTATION CONTROL (REPETITION RATE)
SENDING DISTRIBUTOR
COMMON CIRCUIT
RECEIVING DISTRIBUTOR
SYNC SLAVE
ROTATION CONTROL (REPETITION RATE)
DERIVED CIRCUITS ASSUMED SENDING TERMINAL
DERIVED CIRCUITS RECEIVING TERMINAL

Figure 2. A scheme illustrating the basic theory underlying time-division multiplexing systems. The refinements required to handle speech signals are responsible for the detailed differences between the above system and those actually used. Additional refinements are required where there will be any limitation of bandwidth by the transmission path indicated as the common circuit. Radio usually will provide this circuit

The multiplexing carriers are obtained from a carrier supply panel. As can be seen from Figure 4, the carrier supply panel provides three carrier frequencies for both the sending and receiving translators, and, in addition, delivers a 1-kc signal for testing and signaling purposes.

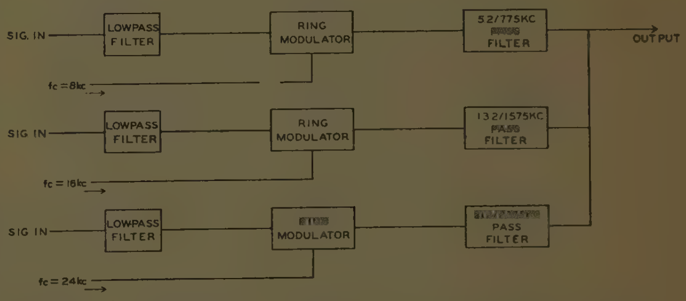


Figure 3. Multiplexing translator panel block diagram showing the arrangement of parts, electrically and mechanically, for three multiplexed circuits

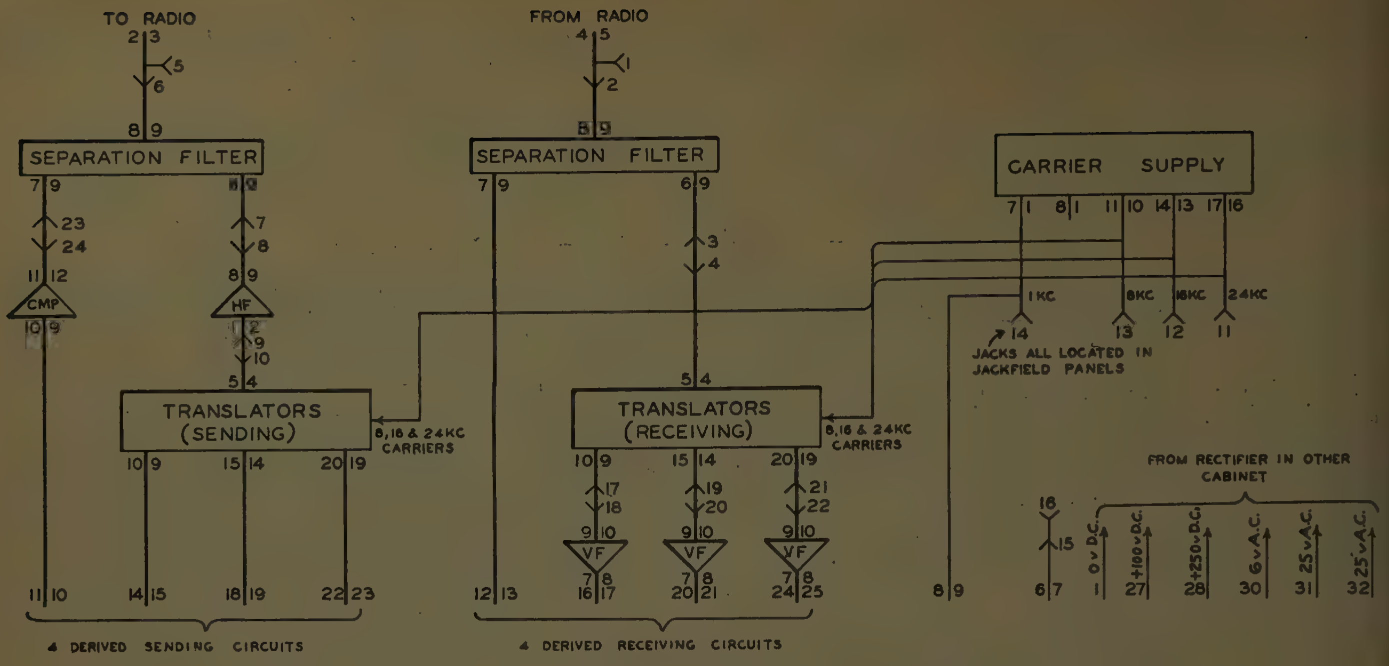


Figure 4. Block diagram of 4-circuit multiplexing equipment used in the field test program

Two terminals of this model equipment were built and placed in service with a microwave radio system in August of 1949. As shown in Figure 4, each terminal provided four 1-way circuits in each direction with all circuits and panels arranged with connections through a jackfield.

Each translator panel contains three translator circuits that are electrically independent except for a common output circuit, see Figure 3. The devices are insensitive to direction and can be used either for sending or receiving. The only difference between the translator circuits is in the passband of the band-pass filter used between the ring-modulator circuit and the common output circuit to select the desired sideband. It then becomes obvious that if each translator circuit is used with a different carrier frequency, its band-pass filter must be co-ordinated to the carrier frequency. The carrier frequencies used in the field-test equipment were 8, 16, and 24 kc, and filter passbands were 5.2 to 7.75 kc, 13.2 to 15.75 kc, and 21.2 to 23.75 kc.

Referring again to Figure 3, the signal path for sending is through a low-pass filter to the ring-modulator circuit where the signal combines with the carrier frequency. The output of the modulator circuit contains both sidebands, but the carrier is almost entirely absent. The output is delivered to the band-pass filter which is designed to offer only slight losses for frequencies in the lower sideband range, but sharply attenuates all frequencies outside of that range. The low-pass filter is required for the following reasons:

1. To restrict the frequencies of those signals to be transmitted to the required bandwidth.
2. To pass only the desired lower sideband when used in the receiving direction.
3. To prevent variations of impedance in the ring-modulator circuit from being closely coupled to the external circuits connected through the filter.

The ring-modulator circuit used in these translators is shown in Figure 5. The use of contact rectifiers is justified by a number of important reasons:

1. They are obtainable with characteristics more uniform than found in vacuum tubes. This permits eliminating all ring-modulator balance adjustments.
2. They require no plate and filament power.
3. They have no filaments or heaters to burn out.
4. They are not mechanically fragile.
5. They have no cathodes to lose emissivity.
6. They require an insignificant amount of space.
7. They require no socket.

Technical literature contains a number of articles dealing with the use of copper-oxide rectifier elements as modulators and demodulators.[1–4] Each of the referenced articles contributed to the modulator circuit of Figure 5. Figure 6 shows a typical curve of the resistance of a copper-oxide disk as a function of the applied voltage. Perhaps the simplest way of explaining how the modulator operates is to treat the copper-oxide ring unit as a double-pole double-throw reversing switch used to connect the output of T_1 to the input of T_2. This connection is poor if each of the four arms of the ring has the same value of resistance, since they form a shunt across the connection between the transformers, and their unpolarized resistance, 20,000 ohms or more, is also in series with the connection. If direct current is applied to the leads marked "carrier," with polarity and voltage sufficient to cause CR_{1A} and CR_{2B} to become conducting, it will be observed that CR_{1B} and CR_{2A} are polarized at the same time so that they are less conducting. In this condition of unbalance, CR_{1A} and CR_{2B} form low-resistance connections between terminals *1* and *4* of T_1, and terminals *1* and *4* of T_2, permitting signal current to be transferred through the system with small loss. When the polarity of the direct current is reversed, CR_{1B} and CR_{2A} become conducting and CR_{1A} and CR_{2B} become highly resistive. The connection between T_1 and T_2 still exists, but now terminals *1* and *4* of T_1 are connected to terminals *4* and *1* of T_2—a reversal of the connection.

If an a-c polarizing voltage is substituted for the d-c polarizing voltage, T_2 will deliver an output controlled by the frequency, amplitude, and polarity of the applied alternating voltage. If the alternating voltage effective at the copper-oxide elements approximates a square wave, this output would have the appearance shown in Figure 7. It is necessary that the carrier (polarizing) voltage at all times exceed the drop produced by the flow of signal currents when they are of opposite polarity. If this excess has insufficient margin, the copper-oxide resistance will increase and cause nonlinearity of signal output. The slope of the conducting part of the curve in Figure 6 suggests that such distortion will always be present to some degree. If, in addition to insuring that the carrier voltage is always more than adequate to maintain polarization, fixed resistance is added in series with the copper-oxide element (setting the minimum resistance in the conducting direction to be large compared to the conducting resistance of the copper oxide), then the small resistance variations can be made to be an insignificant percentage of the total resistance. As a result of employing both of these measures, distortion measurements of 0.5 per cent and less were obtained for a voice circuit through a sending and receiving translator system with filters but without amplifiers or radio.

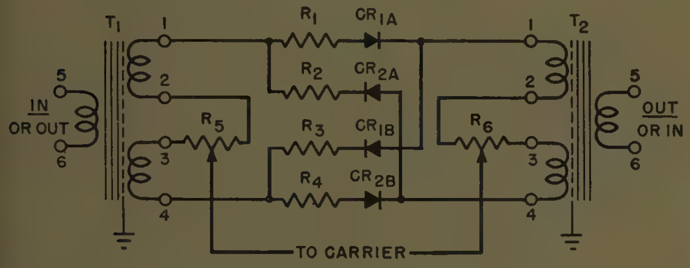


Figure 5. **Schematic for ring modulators used in the translator panels. Copper-oxide rectifier elements are used in the ring circuit with series-connected resistors which improve both the overload characteristics, and the balance of the bridge circuit. R_5 and R_6 are provided for vernier adjustment of carrier and noise suppression**

The operation of the ring modulator was compared previously with the action of a double-pole double-throw switch connected to reverse the polarity of the path between input and output. This suggests that the carrier signal applied to the ring modulator should be a square-wave carrier. In practice it is customary to use a rather large carrier amplitude, supplying it to the ring modulator through an external resistance which acts as a current-limiting device.[4, 5] However, signal currents still must be kept small compared to the carrier. Nonconducting elements in the ring modulator will overload with a signal less than one-tenth that required to overload the conducting elements. The use of resistance in series with each element of the ring can radically reduce this difference. A further result of the addition of the fixed resistors in the ring modulator is the marked improvement obtained in the balance of the circuit. It can be obtained, of course, only if the resistors used are sufficiently well balanced.

Filters are used at several points in this equipment, as can be seen in Figures 3 and 4. In Figure 4 two separation filters are shown. Each consists of a low-pass filter, with cutoff at 2,800 cycles, and a high-pass filter with its cutoff at 5,200 cycles. They are used to apply a separate or direct voice-frequency band to the radio transmitter without frequency translation. By applying it through the low-pass filter, the bandwidth of the voice-frequency circuit is restricted to frequencies below about 2,800 cycles, insuring that no higher frequencies accidentally or intentionally present in the voice-frequency circuit will interfere with the high-frequency signals delivered by the translators.

By design, the impedances of all filters are about 600 ohms in their passbands only. Outside these bands the impedances rise to much higher values. Thus, the outputs of two properly designed filters with passbands in different parts of the spectrum can be paralleled and connected to a 600-ohm circuit. Such isolating properties are quite important to the frequency response of the derived circuits.

It is conventional to use free-running local oscillators for supplying the multiplexing carrier frequencies. Thus, the signal frequencies recovered at the receiving terminal in a single-sideband system will differ from the original signal frequencies by the frequency difference between the sending and receiving carrier oscillators. Recovery of speech signals is quite satisfactory even though such differences are as high as 20 or more cycles. Maintenance

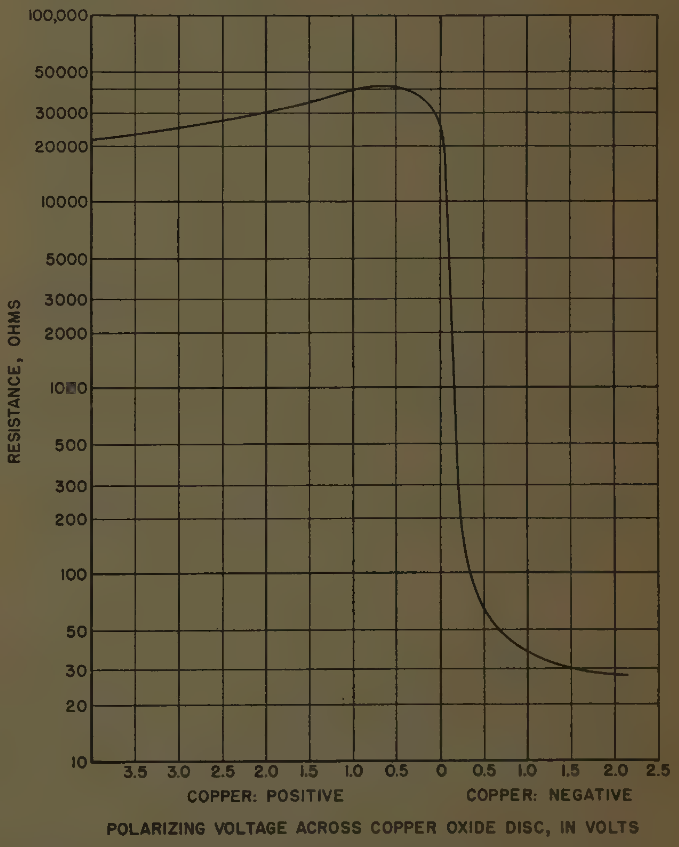
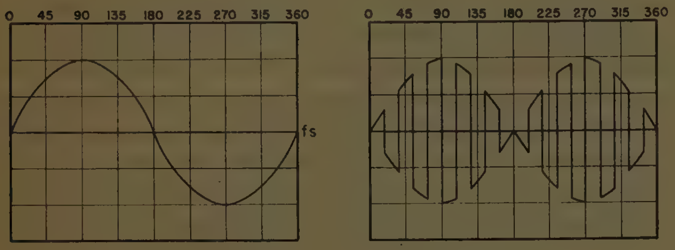


Figure 6. **Resistance as a function of applied voltage for a copper-oxide rectifier cell**

adjustment of these oscillators is required only to keep speech intelligible and as natural as the user requires.

Some forms of telegraphic services, when handled over one of the multiplexed voice circuits, cannot tolerate these rather large differences between original and recovered signal frequencies. This is due partly to the narrowness of the receiver filter, which cannot reasonably be broadened. It is further complicated by the fact that the telegraph-sending oscillators may not be perfectly stable or may not have zero temperature coefficients.

Carrier oscillators require careful design to minimize the effects of temperature and voltage variations. They must include provisions for adjusting their output frequency, and may also contain output-level regulating means. When high accuracy is required of the recovered signal, the local oscillators at the receiving terminal may be controlled automatically by a carrier or synchronizing signal transmitted between terminals, possibly on the pilot frequency. Another method is to transmit some of the sending-end carrier over the system and recover it for demodulation purposes at the receiving terminal.



(A) SIGNAL INPUT TO T_1 (B) SIGNAL OUTPUT OF T_2

WHEN CARRIER FREQUENCY IS SQUARE WAVE 10 x fs

Figure 7. Input signal versus output signal for the ring modulator, assuming an applied carrier having a frequency ten times that of the signal f_s and of square wave form

Local oscillators and their associated adjustments and maintenance requirements are not desirable for the type of multiplexing equipment which would be most suitable for use in electrical-utility communication systems. A carrier supply system should be so precise and stable that it requires no maintenance of frequency.

With the multiplexing carriers spaced four kilocycles apart, this frequency could be made the source of all carrier frequencies required by the assignments shown in Figure 1. Study of ways and means for obtaining four kilocycles with an accuracy and stability within about 0.001 per cent was begun and it was found that a temperature-compensated fork frequency standard offered the surest and simplest source of the required signal. A 1,000-cycle fork using one *6SN7* tube for drive and output was decided upon and the block diagram for the carrier supply system took the form shown in Figure 8. The output of the fork unit is used to obtain the 1-kc test signal and results in delivering three carrier frequencies (8, 16, and 24 kc) of approximately square wave form.

The fork standard unit was purchased as a complete tested and calibrated assembly and was mounted directly upon the carrier supply panel. The fork itself is in a partially evacuated metal container which protects it from atmospheric changes, corrosion, and tampering. It is of bimetallic construction, and the resulting temperature coefficients are better than 0.0001 per cent per centigrade degree between 0 and 100 degrees centigrade. The unit is set to 1,000 cycles within 0.0001 per cent at the factory. A vernier frequency adjustment is provided which has a range of about 0.0005 per cent, or only 0.05 cycle at 1,000 cycles. If another 0.05-cycle error is added for a temperature difference of 50 degrees centigrade, the total difference in frequency of the forks might be about 0.1 cycle. This amounts to 2.8 cycles for the 28-kc carrier in this system, or an error in the recovered signal frequency of 1.13 per cent for a signal of 250 cycles. The fork is electromagnetically driven, polarized by a small permanent magnet, and includes a grid (pickup) coil and a plate (drive) coil.

The schematic of the basic frequency doubler used in this panel is shown in Figure 9*a*. C_1 and C_2 are chosen to obtain maximum accentuation of the ripple output of the bridge-connected rectifier, but commercial tolerances are good enough and no adjustments are required to obtain satisfactory operation. The value of R is determined roughly by the safe amount of direct current which can be handled by the rectifier. It has little effect upon the ripple amplitude in the range used. Each doubler has the same schematic. As frequency increases, transformers, capacitors, and resistors also change correspondingly.

When the desired carrier frequency falls between those obtained by the doubling process, two of the frequencies already obtained are selected and applied to the grids of the mixer circuit of Figure 9*b*. Mixing takes place in the plate circuit and the three frequencies then present are coupled to a high-Q resonant circuit adjusted for the desired frequency. The range of the adjustable capacitor permits peaking, but will not prevent operation on fre-

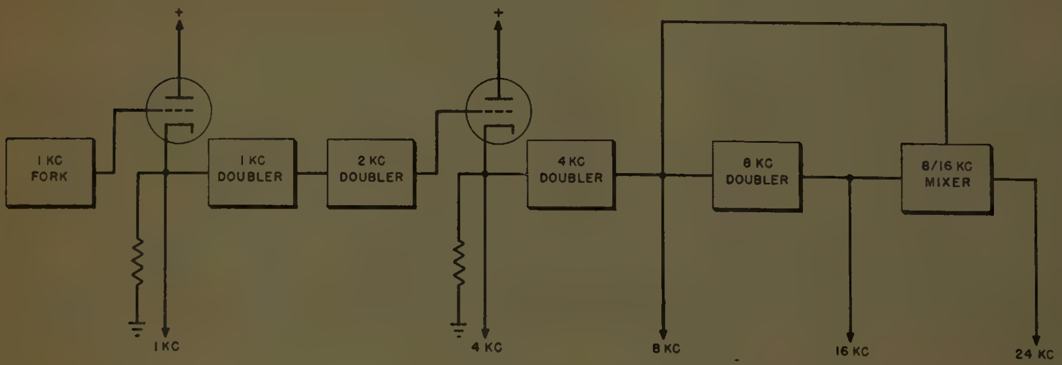


Figure 8. Block diagram of carrier supply system showing method of obtaining the output signals required. The 8-, 16-, and 24-kc outputs are converted to square wave output before being used for multiplexing carriers

quency unless it is short-circuited. The entire carrier supply system can be placed in operation with no adjustments of any sort required to obtain correct operating frequencies.

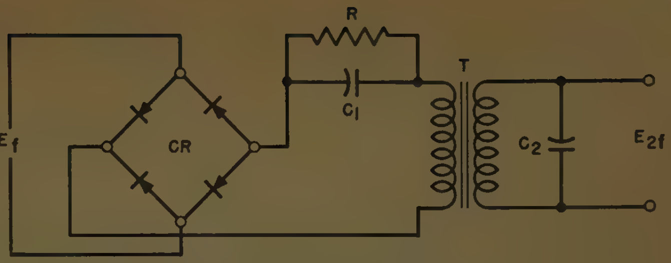
The data which follow give the performance first obtained over the radio circuit between Hilltop (Johnstown, Pa.) and the temporary location of the Seward terminal at Armagh. This radio circuit involved a line-of-sight path which grazes Conemaugh Gap at least at one point. Measurements were made on all circuits terminated at each end with 600-ohm carbon resistors. The three derived circuits were set up for regular telephone service and were measured with hybrids balanced for the resistive terminations and with amplifier gains adjusted to give zero net-loss circuits in each direction. Frequency response for the Piney circuit, multiplexed with an 8-kc carrier, with respect to the level of the 1,000-cycle reference, was down 3.7 decibels at 250 cycles and down 9.0 decibels at 2,800 cycles. The data showed that there was a need for equalization, somewhat under six decibels per octave, to give a circuit response flat within six decibels.

Frequency response of the Altoona circuit (16-kc carrier) was down six decibels at 250 cycles and down 5.5 decibels at 2,800 cycles. The Glory circuit (24-kc carrier) was down seven decibels at 250 and 2,800 cycles. These frequency responses provide excellent talking circuits, and are flat enough to permit being equalized within one or two decibels where very strict requirements exist.

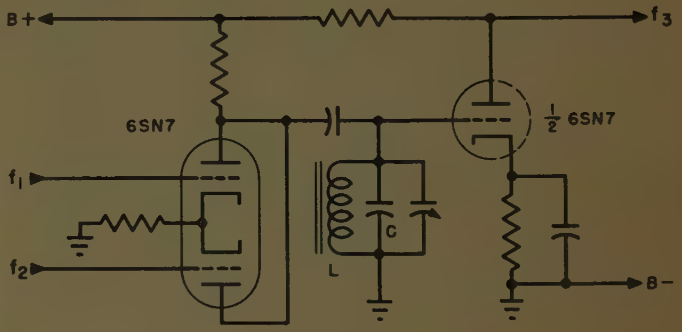
In testing this multiplexing equipment in the laboratory before shipping into the field, the measured noise levels in all circuits were more than 65 decibels below 0 dbm (decibels below one milliwatt). Measurements in the field varied, largely due to conditions in the radio circuit, and were never as good as found in the laboratory. The Piney (8-kc) circuit showed noise levels from 35 to 48 decibels below 0 dbm. The Altoona (16-kc) circuit had noise levels from 41 to 48 decibels below 0 dbm. The Glory (24-kc) circuit recorded 38 to 60 decibels below 0 dbm. Usual readings for all three circuits gave noise levels more than 40 decibels below 0 dbm.

Use of the usual noise and distortion meter was unsatisfactory because harmonic distortion was found to be less than the noise readings. It was necessary to measure distortion in terms of intermodulation percentage. This system permits filtering out most of the noise since it operates on signals having levels higher than the noise level. Intermodulation percentages were found to run from one to five per cent. Experience indicates that 4-per cent intermodulation distortion compares with about 1-per cent harmonic distortion.

Crosstalk tests were made with the aid of a special device. It consisted essentially of six magnetic-tape playback heads with separate amplifiers and output circuits, and a single-drive motor, shaft, and tape-pulling arrangement. The noise meter was used to measure any increase in noise level as being the contribution made by crosstalk. At no time was crosstalk responsible for raising the noise level more than two decibels. Simultaneous listening tests showed that crosstalk was very slight.



(a)
FREQUENCY DOUBLER



(b)
FREQUENCY MIXER

Figure 9. Carrier supply circuit. When a signal of frequency *f* is applied to the doubler input terminals of circuit *a*, a new frequency 2*f* is obtained at the output. In circuit *b* the frequencies f_1 and f_2 are chosen so that their difference will equal one of them, while their sum will equal the desired new frequency f_3. The filter is resonant at the frequency f_3

The radio circuit will introduce most of the noise, distortion, and crosstalk, and great care should be taken to see that the radio line-of-sight path is as nearly ideal as is possible. Where the full capabilities of the multiplexing equipment are to be required, in other words seven voice circuits with 50-decibel signal-to-noise and crosstalk ratio, it becomes extremely important to apply the radio circuit conservatively, making certain that 50 feet of clearance are obtained to the line-of-sight for the radio beam.

Heaters are operated at about five per cent below rated voltage, and the *6SN7* tubes have an excellent record even at normal heater voltage. Emission requirements are always less than tube ratings, and in most cases are about 50 per cent less. Since no tube is operated at a critical point on its characteristic curve, any good tube will work until emission fails to meet the load.

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Resistance Commutation

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THE MANY important military, industrial, and domestic applications of commutator machines make it necessary that designers know the commutating ability of these machines. For machines using commutating poles within their range of effectiveness, the commutation behavior can be forecast with reasonable accuracy. However, where the varying resistance of the brush-to-bar contact is depended upon to control the commutation, that is, resistance commutation, there is a need for fundamental design information on which may be based calculations of commutation performance from circuit data.

The commutator machine discussed in this article is operated at constant speed from a constant-voltage line and has symmetrical windings in which commutation is accomplished in the neutral zone by means of brushes which span one commutator bar. The commutator of this machine may be thought of as a number of contacts connecting individual armature coils to the power line in such a manner that, as a coil is disconnected from the power line, it is short-circuited by the brushes, the polarity is reversed, and it is reconnected to the power line, with all of these functions occurring simultaneously. A simplified equivalent circuit (see Figure 1) for this process has been developed which contains the essential geometry of the machine as far as commutation is concerned, but which omits complicating factors that can be given separate consideration. This equivalent circuit includes inductance in the armature coils which are not commutating, and analysis shows that this noncommutating inductance has important effects on every aspect of the commutation problem.

If the noncommutating inductance is considered to be extremely large, the theory of commutation presented by Thorburn Reid[1, 2] is obtained as a special case of the general problem. For the values of noncommutating inductance met in practice, a general analytical expression of commutation behavior based on the simplified equivalent circuit makes it possible to calculate commutation performance without having to resort to infinite series expansions or evaluation of indeterminate expressions which have plagued previous analytical work on commutation.

Three of the major elements of the commutation problem encountered in the design of commutator machines are the calculation and test measurement of the electric brush wear, the brush terminal voltage, and the commutating reactance. Test confirmation of a direct relation between abnormal electric brush wear and reactance voltage (reactance voltage is the average value of the voltage developed by the reactance of the commutating coil during reversal of current in the coil) has been made, using an inverter (see Figure 2) which is a counterpart of the simplified equivalent circuit. This test method offers the possibility of obtaining fundamental information concerning the effect of quality of commutation upon electric brush wear, and should aid in the development of improved brushes by permitting a measurement of the comparative commutating ability of various brush grades under controlled commutating conditions.

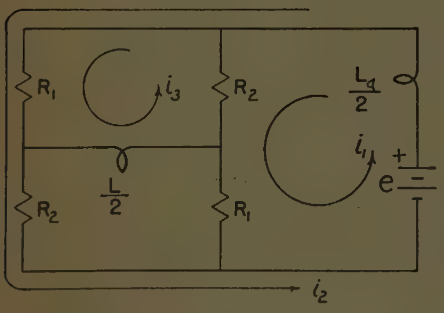

Figure 1. Simplified equivalent circuit of the commutator machine

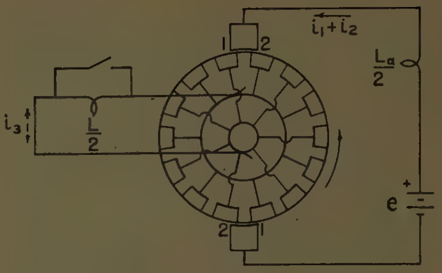

Figure 2. Commutation tester

The brush terminal voltage is an index to the severity of the commutating conditions and directly affects the voltage regulation and short-circuit current of generators, speed regulation of motors, commutator and brush temperature, and so on. Values of brush terminal voltage reaching many times the normal brush contact drop are predicted by analysis of the simplified equivalent circuit and are confirmed by test measurement under severe commutating conditions.

Test measurement of the magnitude of the commutating reactance is made possible by connecting a rotating inverter to the stationary armature so that simulated commutating conditions are obtained. In this way, difficulties with armature reaction and pole face losses which occur with a rotating armature are avoided, and there is no question as to the proper frequency at which to measure the commutating reactance, since the actual commutation period is duplicated.

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Dielectric Relaxation in Liquids and Solids

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The third in a series on dielectrics, this article summarizes the knowledge of the phenomena of dielectric relaxation in both liquid and solid materials. The existence of relaxation is noticeable when it occurs at a rate near the rate of the change of force causing the relaxation.

RELAXATION is the lag in the response of a system to change in the forces to which it is subjected.[1] It is thus a rather general phenomenon whose existence becomes apparent when its rate is not far from being of the same order of magnitude as that of the change of the applied forces. It may consist, for example, of lag in response to the following conditions: a change of temperature which affects the determination of thermal properties; a change of stress which affects mechanical stretching or viscous flow; or a change of electric field which tends to lower the dielectric constant. The relaxation rate is the rate at which a system comes into equilibrium with its surroundings when such a change occurs. When the relaxation rate is very different from that of the change of the constraining influence, the process involving the relaxation may not be noticed. For example, when a dielectric constant is measured at a frequency which is very low or very high in comparison with the dielectric relaxation rate, no loss of energy is observed.

DIELECTRIC POLARIZATION AND RELAXATION

DIELECTRIC RELAXATION occurs in the polarization of matter and, in particular, when a capacitor is charged, a process which always involves rapidly forming or instantaneous polarization and may also involve slowly forming or absorptive polarization.[2] From a structural point of view, the most interesting dielectric relaxation is that involving orientation polarization, which depends on the internal structures of the molecules and on the molecular arrangement or structure of the dielectric. In terms of the theory of this phenomenon, as developed by P. Debye,[3] dielectric relaxation is the lag in dipole orientation behind an alternating electric field. Under the influence of such a field, the polar molecules of a system rotate toward an equilibrium distribution in molecular orientation with a corresponding dielectric polarization.[4] When the polar molecules are very large, or the frequency of the alternating field is very high, or the viscosity of the medium is very great, the rotatory motion of the molecules is not sufficiently rapid for the attainment of equilibrium with the field. The polarization then acquires a component out of phase with the field, and the displacement current acquires a conductance component in phase with the field, resulting in thermal dissipation of energy.

The fundamental equations of these phenomena have been described in another article of this series. R. H. Cole[5] has introduced an empirical modification of the Debye equations capable of reduction to the Debye equations or to equations corresponding approximately to L. Onsager's treatment[6] of the internal field. These latter equations seem to be closer to experimental fact[5,7] than the original equations.

Equations of similar form can be derived for the interfacial polarization[8–10] of a 2-layer capacitor[11] and applied to an inhomogeneous dielectric without reference to any theory of microstructure. It merely happens that equations of the same form describe two quite different phenomena which may occur separately or simultaneously in an inhomogeneous dielectric.

Although liquids may conform to the behavior demanded by these equations, the dispersion commonly occurs over a wider frequency range, with a maximum value of the loss factor ϵ'', lower than that predicted. This effect has been attributed to a distribution of relaxation times. The different distribution functions for relaxation times which have been developed[4,9–14] have been shown[1] to give results almost indistinguishable from one another experimentally.

According to Debye's treatment,[3] the relaxation time

$$\tau = 4\pi\eta a^3/kT \tag{1}$$

in which the molecule is pictured as a sphere of radius a rotating in a medium of viscosity η.

ANALYSIS OF DIELECTRIC MEASUREMENTS

FOR THE EARLY WORK on the anomalous dispersion of the dielectric constant, it was necessary to compensate for the absence of high frequencies for the measurements by using high viscosities in order to reach the region of anomalous dispersion. Glycerol, alcohols at low temperatures where the viscosity was high, and solutions of a few polar substances in heavy oils were measured at wavelengths between 0.5 and 300 meters. Commonly, the dispersion region was reached or traversed by lowering the temperature and thus increasing the relaxation time both by the decrease in temperature and by the large increase in viscosity which accompanies decrease in temperature. The general trend of the dielectric constant and loss factor values corresponded well to the requirements of the Debye equations. For several alcohols the

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This is the third in a series on dielectrics. See "Dielectrics in Electrical Engineering," A. von Hippel (*EE, Sept '50, pp 771–3*) and "Structure and Polarization of Atoms and Molecules," J. C. Slater (*EE, Oct '50, pp 872–5*).

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values of the molecular radii calculated from the relaxation times were of reasonable magnitude, but the radii obtained for the glycerol, nitrobenzene, and several other molecules were much too small, sometimes about a tenth of what they should be.[15] Since it is a familiar fact that the Debye equation for the static dielectric constant is applicable only to gases and dilute solutions, the value of τ is really obtained as that of an adjustable constant which enables the equations to reproduce fairly well the observed values of the dielectric constant and the loss factor.

Dielectric loss has been determined by standard a-c bridge methods, by measurements of resonance and damping, and by absorption and reflection methods analogous to those used in optics.[15, 17, 18] A quite different method which has been used, particularly on solutions of electrolytes but also on other liquids, is the determination of loss factor by measurement of the heat evolved in a liquid as the result of the absorption of electric energy.[19–29]

MICROWAVE MEASUREMENTS ON LIQUIDS

The modern development of microwave techniques has extended the range of accurate measurement of dielectric constant and loss to frequencies so high that anomalous dielectric dispersion may now be studied for even the smallest polar molecules in the liquid state. Measurements have been carried out upon pure polar liquids and upon solutions of polar molecules in nonpolar liquids. Curves have been drawn to represent satisfactorily the solution loss tangent as a function of frequency, and dipole moment values have been calculated for the polar molecules in fair agreement with those obtained from static dielectric constant measurements.[30–33] Measurements of dielectric constant and loss factor have also been made on solutions of electrolytes and found to be capable of representation by the Debye equations.[34]

The dependence of relaxation time and of the distribution of its values upon molecular size, shape, and rigidity, and upon the viscosity of the medium has been investigated recently[16,35–37] by means of measurements of dielectric constant and loss at wavelengths of 1, 3, 5.6, and 10 centimeters. The relaxation times or critical wavelengths of the straight-chain alkyl bromides increase regularly with increasing chain length from ethyl to hexadecyl bromide. On the basis of equation 1, the relaxation time should, if the viscosity and temperature remained constant, increase linearly with the cube of the molecular radius, which is proportional to the number of carbon atoms in the molecule. An almost linear dependence of the relaxation time or critical wavelength upon the number of carbon atoms was observed[16] at 55 degrees centigrade, but, at lower temperatures, the curves for critical wavelength versus number of carbon atoms in the straight chain showed an increasing upward slope, with increasing chain length as all of them should, since the viscosity, instead of being constant, increases rapidly with increasing chain length. The decrease in the rate of change of the slope of the curves as the temperature rises suggests that, with increasing temperature, dipole orientation may occur not only by orientation of the molecule as a whole but also by rotation around the carbon-carbon bonds of the chain. This latter type of orientation becomes increasingly possible as the number of carbon-carbon bonds increases with increasing chain length and as the temperature rises. The twisting of a portion of the molecule by rotation around a bond is hindered by neighboring molecules and may require some displacement of these molecules. Consequently, the critical wavelength should still increase with the viscosity of the liquid even if dipole orientation were occurring wholly through internal rotation in the molecule.[38] A close parallelism between critical wavelength and viscosity is shown when the two quantities are plotted against the number of carbons for the straight-chain alkyl bromides as the curves are remarkably similar in form.

As previously noted[5, 7, 15] the qualitative character of the relation between relaxation time, viscosity, and radius given by equation 1 is emphasized when it is used to calculate the molecular radius a or a molar volume, $4\pi Na^3/3$. For the almost spherical t-butyl bromide molecule, for which the equation should be at its best, the radius value obtained is 1.4 Ångstrom units as compared to an approximate van der Waals radius, 3.7 Ångstrom units, calculated from the bond radii and van der Waals radii of the atoms. The molar volumes calculated by equation 1 are much smaller than those observed by other methods. Although the values for the straight-chain molecules should obviously increase linearly with increase in the number of carbon atoms in the molecule, as do the molar volumes calculated from densities or refractions, the values calculated for the n-alkyl bromides rise to a maximum for the 6-carbon chain and then decrease until the value for hexadecyl bromide is close to that for ethyl bromide.[16] This behavior is in accord with the idea that the average orienting unit in the longer molecules is smaller than the molecule as a whole, and that dipole orientation may occur through twisting around the carbon-carbon bonds of the molecular chain.

An interesting example of intramolecular orientation of dipoles has been observed[39,40] in the polyesters of ω-hydroxydecanoic acid in dilute benzene solutions, which show no evidence of anomalous dispersion of the dielectric constant at frequencies where it is to be expected for molecules of such size. Over a 15-fold range of the molecular weight of the polymers, the specific polarization remains essentially constant and the apparent molecular dipole moment varies as the square root of the molecular weight. It is evident that the molecule does not move as a whole, but that there is sufficient freedom of rotation around the bonds to permit orientation of the dipoles within the molecule. Here dipole orientation occurs entirely by intramolecular twisting, while in the alkyl bromides the small molecules orient as units, and in the large molecules dipole orientation occurs, at least in part, by means of intramolecular motion.

The microwave measurements on the organic halides have shown that the dielectric behavior of four liquids out of 27 investigated conforms closely to that required by the Debye theory of anomalous dielectric dispersion with a single relaxation time. The shapes of these four molecules, i-propyl, i-butyl, s-butyl, and t-butyl bromide, are not far from the spherical form postulated in the derivation of the Debye equations. It is only for these nearly spherical molecules that one might expect close conformity to the Debye equations. Increasing molecular chain length gives increasing departure from the Debye equations and requires an increasing width in the distribution of relaxation times. Rising temperature reduces the distribution of relaxation times so that a number of moderately unsymmetrical molecules conform fairly well to the Debye equations at 55 degrees centigrade.

The very close parallelism between critical wavelength or dielectric relaxation time and viscosity in dependence upon molecular size and temperature gives evidence of the previously observed similarity between the processes of dielectric relaxation and viscous flow. This similarity is further emphasized in the behavior of the activation energies, free energies, and entropies of the two processes.

Measurements of microwave absorption in solutions of polar molecules in nonpolar solvents provide a means of studying the effect of variation in the viscosity of the medium while the other factors influencing dielectric behavior remain constant. In Table I are assembled values of critical wavelengths from various sources.[7, 16, 31, 37, 41] The second and third columns give the viscosities and critical wavelengths of the pure solutes listed in the first column when the critical wavelengths are available. The subsequent columns give the critical wavelengths of the solutions in the solvent listed at the top of each column. The viscosity of each solvent is given below its formula.

It is evident that the critical wavelength for the pure polar liquid is higher than that for any of the solutions, although the viscosity is sometimes lower. If a solvent of viscosity much higher than that of hexadecane is used, the critical wavelength becomes longer than that of the pure solute, as shown by the results of D. H. Whiffen and H. W. Thompson,[31] who find for a dilute solution of chlorobenzene in a mixed cyclohexane-paraffin solvent of viscosity about 80 times that of cyclohexane, a critical wavelength about four times that in cyclohexane and, therefore, about three times that in the pure polar liquid. For both ethyl benzoate and chlorobenzene solutions, successive additions of the viscous paraffin to the dilute solution in cyclohexane increases the viscosity some 80 times, while increasing the critical wavelength four to seven times. Similarly, W. Jackson and J. G. Powles[30] have found a relaxation time or critical wavelength for benzophenone in dilute solution in medicinal liquid paraffin 18 times that in benzene, while the viscosity of the paraffin is 298 times that of the benzene. Jackson and Powles regard this result as confirming "the well-recognized inadequacy of the Debye relation connecting the relaxation time of dipole orientation and the macroscopic viscosity," and Whiffen and Thompson conclude that the relaxation time is "far from being proportional to the macroscopic viscosity" as required by equation 1 and that "η should be regarded as an internal viscosity coefficient." It was as an internal viscosity coefficient that Debye used η in deriving equation 1, but our ignorance of the internal friction or viscosity coefficient has necessitated the use of the measured viscosity as an inferior substitute.

Table I. Critical Wavelengths in Centimeters and Viscosities in Millipoises at 20 Degrees Centigrade

Solute	Pure Solute		Solutions			
	η	λ_m	n-C_7H_{16} $\eta=4.16$	C_6H_6 $\eta=6.47$	C_6H_{12} $\eta=9.7$	n-$C_{16}H_{34}$ $\eta=36$
Ethyl bromide	4.02	0.76	0.3	0.6	0.4	0.4
n-Octyl bromide	16.5	4.6	2.07		3.14	3.64
t-Butyl chloride	5.3	1.0	0.3		0.3	
Chloroform	5.6	1.4	0.58	1.34	0.60	
Chlorobenzene	8.03	2.05		1.56	1.47	
Bromobenzene	11.6	3.35		2.00	1.96	
α-Bromonaphthalene	49.8	17.6	2.69 2.45			
d-Camphor			1.22	1.79	1.34 1.72	

A very small loss, too small to affect the dielectric constant by a measurable amount, has recently been observed at microwave frequencies in a number of pure nonpolar liquids, such as heptane, benzene, and carbon tetrachloride,[42–44] for whose molecules no permanent dipole moments have been found. The losses correspond to dipole moments of about 0.05×10^{-18} and relaxation times of about 10^{-12} second. It has been suggested[43] that the dipole moment may be induced in a molecule by a neighboring molecule and that the induced dipole will change direction, not by rotation of the molecule containing it, but because of a new distortion produced at a later instant by another neighbor. The very short relaxation and the very small moment are thus qualitatively accounted for, but more work is necessary for confirmation of both experimental observations and the interpretation.

FREEDOM AND RELAXATION IN SOLIDS

THE UNCERTAINTY of the relationship between dielectric relaxation and the macroscopic viscosity of the material is even more evident in the case of solids. When the molecules of a liquid are polar, as in the case of nitrobenzene which has a large dipole moment, solidification normally effects a sharp drop in dielectric constant because of the elimination of orientational freedom, which causes the disappearance of the contribution of the permanent dipole moment, and leaves only the relatively small contribution of the induced dipole moment. In the absence of a permanent dipole in the molecule, the presence or absence of orientational freedom has little effect on the dielectric constant and ϵ'' is zero. The increase in density on solidification increases the amount of polarizable material per unit volume and thus increases the dielectric constant by a small amount. The normal behavior of the dielectric constant, on solidification, therefore, is usually a large drop if the molecules have permanent dipoles, or a slight rise if they are nonpolar.

The specific heats of certain solids consisting of small molecules, not far from spherical in form, suggested the existence of molecular rotation and the existence of rotational freedom was indicated by the high dielectric constants and approximate Debye behavior found for solid hydrogen chloride,[45, 46] hydrogen bromide,[46] hydrogen iodide,[46] hydrogen sulfide,[47] and arsine.[48] It is characteristic of these small molecules, not far from spherical in form, that their lattices are anisotropic below the rotational transitions and isotropic, like those of closely packed spheres, above the transitions.[49] The heats of fusion of these solids are usually abnormally small, smaller than the heats of transition, and the corresponding entropies of fusion are often[50] close to the two entropy units calculated[51] for a substance already having rotational freedom.

The molecules of a solid at low temperature may be pictured[52] as not only vibrating in short paths about points fixed in a lattice but also executing rotational vibration about their individual centers of gravity, the energies of both types of vibration increasing with rising temperature. The rotational oscillation of the molecule is about an orientation of minimum potential energy. If the molecule acquires sufficient rotational energy before the melting point is reached, it should rotate from one potential energy minimum to another in the solid. In this "rotator" state, the molecules are not rotating freely but are merely possessed of sufficient energy to permit a fairly frequent passage over the potential barriers hindering rotation. Such rotational freedom is comparable to that possessed by the molecules of a liquid. The rotational transition may be regarded as a change from an ordered to a disordered state.

It was thought at one time that rotational freedom might be limited to small molecules or to cylindrical structures of small radius, the possible rotation occurring around the long axis of the cylinder. However, it was found that the large molecules of camphor and of some of its derivatives,[53–55] which were not very far from spherical in form, showed molecular rotation. The tertiary butyl halides were found[56] to resemble hydrogen sulfide in general behavior, and several other similarly shaped molecules showed rotational freedom in the solid state.[57,58] Rotational freedom has been found[59] in solid penta- and hexa-substituted benzenes, which may be tentatively pictured as very much flattened spheres capable of rotation in the solid only in the plane of the benzene ring. Of the substituted benzenes which show molecular rotation, the less symmetrical cease rotating abruptly at transitions with a corresponding sharp drop in dielectric constant, while the more symmetrical exhibit a region of anomalous dispersion like that of a viscous liquid. A case of rotation about one molecular axis only has been established[60] in *n*-docosyl bromide, *n*-$C_{22}H_{45}Br$, the dielectric constant of which drops sharply on solidification to a value considerably below that of the liquid but well above that of ϵ_∞. A second sharp drop at a transition temperature lowers the dielectric constant almost to ϵ_∞ as the rotational freedom of the molecules around their long axes disappears. In a preliminary experiment described to the writer, Dr. J. D. Hoffman has found the region of anomalous dispersion for the large *n*-docosyl bromide molecule in the solid state to lie at microwave frequencies.

In spite of the extremely high viscosities of these rigid crystalline solids in which molecular orientational freedom has been found, their dielectric relaxation times are evidently so short that no considerable losses have been observed in the kilocycle frequency range generally used in the measurements. This is not true of the more symmetrical penta- and hexa-substituted benzene, which are relatively soft and waxy and behave like very viscous liquids. The coefficient of internal friction hindering the rotational orientation of molecules in rigid crystalline solids is totally different from the externally observed viscosity.

The *n*-tetradecyl, *n*-octadecyl, and *n*-docosyl alcohols show[61] rotation around the long molecular axis in an unstable phase which forms initially on solidification, but dodecyl and the somewhat shorter alcohols do not show it. An abnormally high electrical conductivity and dielectric loss found in this rotator phase were attributed to proton transfer from one hydroxyl oxygen to another facilitated by the molecular rotation. A similar but less pronounced effect was found[62] in long-chain primary amines. This conductivity effect has been observed only in the cases of molecules capable of hydrogen bonding.

The long familiar but never completely understood dielectric behavior of ice[63,64] is interesting in this connection. At first glance, one might expect the H_2O molecule to show rotational freedom in the solid state like that observed in solid hydrogen sulfide. If the dielectric constant is measured with a current of very low frequency, the dielectric constant of ice rises with decreasing temperature from a value at the freezing point close to that of liquid water. With continued decrease in temperature, the change of the dielectric constant becomes negative so that it decreases rapidly toward ϵ_∞. At the same time there is a large apparent conductivity or dielectric loss qualitatively resembling that in the long-chain alcohols and amines but corresponding fairly well to the requirements of the Debye equations. With a frequency no higher than 60,000 cycles, the dielectric constant of the solid is reduced approximately to the optical dielectric constant ϵ_∞ even just below the freezing point. Two principal explanations have been advanced for the dielectric behavior of ice. The obvious one is that the dipolar H_2O molecules are capable of slow rotational orientation in the highly viscous solid medium, whose dielectric behavior is represented almost quantitatively by the Debye equations. The other suggested mechanism depends upon the hydrogen bonds supposed to be binding the H_2O molecules together in the ice lattice. A proton covalently bonded to one oxygen in the lattice and forming a hydrogen bond with a neighboring oxygen may be represented as O–H.....O and is pictured as capable of passing over a potential energy barrier and jumping from the first oxygen to the second to give O.....H–O. This transfer of charge would give rise to polarization with consequent high dielectric constant and loss. It may be treated as a rate process, as that of molecular rotation, so that both processes are capable of representation by the same type of rate equation.[1,65] In view of the behavior of long-chain alcohols and amines, it might be suggested that both processes occur in ice with molecular rotation facilitating proton transfer from one oxygen to another.[38]

GLASSES

MANY ORGANIC LIQUIDS, particularly those whose molecules are irregular in shape or are capable of extensive intermolecular hydrogen bonding, as in the case of glycerol, have been found to form glasses on cooling. The Debye equations represent, at least qualitatively, the dielectric behavior of these glasses.[66–69] The isobutyl and isoamyl halides which have been investigated may be cited as typical. The liquid does not crystallize on cooling, but vitrifies at some distance below the freezing point, and the resulting glass behaves like a very viscous iquid. The relaxation time of the molecules increases with falling temperature and increasing viscosity of the material until the orientation of the molecules lags behind the alternating electric field used in the measurement. The consequent anomalous dispersion of the dielectric constant causes the curve of the dielectric constant versus temperature to separate into branches which unite again when the molecules are entirely unable to orient in the field even of the 0.5-kc current. The curves of loss factor versus temperature resemble those for a viscous liquid. When the glass crystallizes on standing, the liquid-like behavior and anomalous dielectric dispersion disappear.

The dielectric constant of the inorganic glasses depends primarily upon electronic and ionic polarization, and the observed loss commonly depends mainly on the relaxation of the latter. For most glasses, the dielectric constant tends to increase as rising temperature increases the amplitude of the ionic displacement and to decrease very slowly with increasing frequency over a wide range, while the loss is commonly small and subject to only a small change over a wide range of frequency. M. J. O. Strutt[70] has proposed an empirical formula for the dependence of the loss tangent of glasses upon temperature T

$$\tan \delta = K e^{\alpha T} \qquad (2)$$

in which K and α depend upon the composition of the glass and the frequency ω, α decreasing with increasing ω. The following description has been suggested for the mechanism of the relaxation in glasses.[71,72] In the absence of an external field, each alkali metal ion in the glass is vibrating around an equilibrium position in its interstice with a frequency of the order of 10^{12}. If an external alternating field is applied, the equilibrium position changes periodically with the frequency of the applied field. This change of equilibrium position is closely connected with small deformations of the oxygen network around the alkali metal ions, and in this process after-effects occur, which involve a series of excitation energies q, giving rise to the relaxation times τ such that

$$\tau = \tau_0 e^{q/kT} \qquad (3)$$

in which τ_0 is of the order of 10^{-14} second. The empirical constant α in equation 2 is then given by

$$\alpha = -\beta k \log_e \omega\tau_0 \qquad (4)$$

in which β is a quantity depending on a Gaussian distribution of the excitation energies. The presence of cations other than those of the alkali metals may contribute somewhat to the dielectric constant and loss and, in particular, some loss is attributed to the silicon-oxygen network of the glass. Because the rigid structures of the continuous networks of SiO_2 and B_2O_3 glasses do not oscillate readily, these glasses have low losses in the microwave region, but, as at lower frequencies, interstitial cations give rise to losses, which are larger the more loosely bound the cations.[73] Because of the complexity of the composition of most inorganic glasses and the resultant empirical and detailed nature of the treatment required, further discussion of their behavior will not be undertaken.

HIGH POLYMERS

A DETAILED TREATMENT of the dielectric relaxation of high polymers is beyond the scope of this article. Mechanical and thermal relaxation effects have been extensively studied in high polymers. Dielectric relaxation in high polymers involves the factors which have already been discussed for simpler materials. Electronic and atomic polarization always contribute to the dielectric constant. If ionic materials are present, there is ionic polarization. If there are two or more phases of different conductivities present, as in many rubbers and plastics, interfacial polarization occurs with corresponding loss, usually at low frequencies. High polymers containing polar groups show more or less orientation polarization with dipole loss due to change in the orientation of molecular segments in an externally applied field without change in the orientation of the whole macromolecule. The relaxation times of this orientation process commonly have a wide distribution of values, and the corresponding dielectric loss is, therefore, smaller and of much wider frequency range than in the case of small molecules. The dielectric behavior of high polymers has been effectively treated by R. M. Fuoss and J. G. Kirkwood.[4,74–76]

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Asynchronous Transmission Capacity

R. GÅRDING

This article describes a method of computing the asynchronous transmission capacity of a motor, the maximum output which the motor is capable of developing when connected to a given point in a given power supply system.

THE POWER W_2 developed in the rotor shaft of a 30-horsepower motor as a function of the slip at a constant terminal voltage of 380 volts is shown by curve 1*a* of Figure 1. This curve has been obtained from calculations based upon the motor equivalent circuit diagram. With a slip of approximately four per cent, the motor gives its normal output of 22 kw. With a slip of 13 per cent it gives its maximum output of 39 kw. If the load torque to which the motor is subjected at an output of 39 kw exceeds 31.4 kilogram meters $\left(\dfrac{39\times 102}{2\pi\dfrac{1400\times 0.87}{60}}\right)$ the motor will be braked to a standstill.

The curve is calculated on the basis of the following values:

r_2 = rotor resistance, ohms per phase = 0.208
x_2 = rotor reactance, ohms per phase = 0.675
r_1 = stator resistance, ohms per phase = 0.167
x_1 = stator reactance, ohms per phase = 0.675
$g=\dfrac{I_0\cos\varphi_0}{E_0}$, amperes per volt = 0.0075
$b=\dfrac{I_0\sin\varphi_0}{E_0}$, amperes per volt = 0.046
S = slip in per cent
E_p = terminal voltage = 380 volts phase-to-phase
W_2 = output expressed in kw
$W_{2\max}$ = maximum output in kw

If only $W_{2\max}$ is required, it will not be necessary to carry out these calculations for the entire motor equivalent circuit diagram as $W_{2\max}$ can be obtained directly from the approximate formula:

$$W_{2\max}=\frac{E_p^2/2}{z+r+2bx_1(z+r_2)} \tag{1}$$

This equation may be regarded as a generalization of that expressing the maximum output obtainable from a d-c source with an induced electromotive force E_p and having an internal resistance r. This maximum output is obtained if an external resistance r is connected to the d-c source, and is then given by $\dfrac{E_p^2}{4r}$. If equation 1 is applied to direct current, z will equal r and b will be 0. Hence $W_{2\max}=\dfrac{E_p^2}{4r}$.

If the motor is connected to a low-voltage supply, a transformer, and a high-voltage supply, see Figure 2, the resistance and reactance of which cannot be disregarded, the terminal voltage of the motor when running at load will be lower than before. From equation 1 it is evident that $W_{2\max}$ will be diminished, because, in effect, the motor has become weaker although it may remain unaltered in itself. Also, for this case the motor equivalent circuit diagram can be used for calculations as before, provided that the resistances and reactances up to the point where E_p may be considered constant are included in r_1 and x_1 as indicated in Figure 2. In this case it will be necessary to transpose resistances and reactances to low-voltage values, letting E_p denote the low-voltage value of the no-load voltage in the system. It will then be possible to obtain $W_{2\max}$

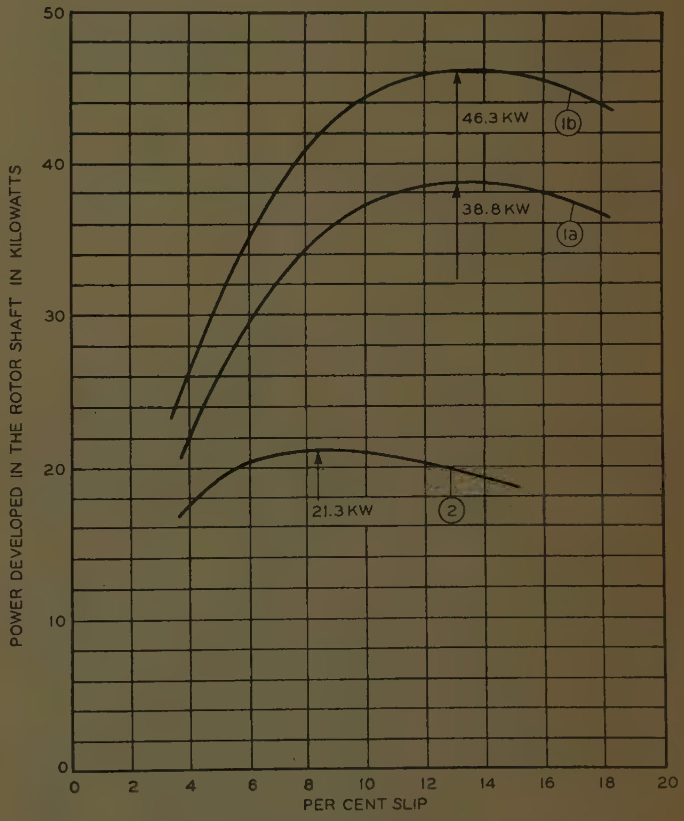

Figure 1. Power developed in the rotor shaft of a 30-horsepower motor versus per cent slip. Curve 1a is with the terminal voltage of the motor held constant at 380 volts. Curve 1b is with the terminal voltage of the motor held constant at 415 volts. Curve 2 is for the transmission system consisting of a high-voltage supply (with negligible resistance and reactance), 50-kva transformer, low-voltage supply 900 meters long, 16 square millimeters of copper conductor. The low-voltage value of the no-load voltage of the system is 415 volts

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directly from equation 1 by inserting the previously mentioned values of r_1 and x_1.

Using this method of calculation, curve 2 of Figure 1 was obtained, indicating the power developed by a 30-horsepower motor which is connected to a high-voltage network by means of a 50-kva step-down transformer and a 900-meter-long 16-square-millimeter 380-volt power line. It is assumed that the voltage of the power supply network remains constant, and furthermore that the no-load voltage applied to the motor is a low-voltage value of 415 volts rather than 380 volts, as it is usual to employ a somewhat higher no-load voltage than the motor rating calls for. It can be seen from the curve that W_{2max} drops to 21.3 kw when the slip is 8.5 per cent. The motor is therefore braked to a standstill at a smaller output and slip than was attained without the transmission system.

Curve 1*b* is the equivalent of curve 1*a* transposed from 380 to 415 volts. A comparison between curves 2 and 1*b* will show that W_{2max} has fallen from 46.3 to 21.3 kw.

The example quoted as follows illustrates the author's method of obtaining W_{2max} directly without having to refer to the motor equivalent circuit diagram.

	r in Ohms Per Phase	x in Ohms Per Phase
High-voltage supply	—	—
Transformer (50 kva)	0.083	0.130
Supply line 0.9 kilometer long, 16 square millimeters copper section	0.99	0.36
30-horsepower motor, stator	0.167	0.675
r_1 and x_1	1.240	1.165
30-horsepower motor, rotor r_2 and x_2	0.208	0.675
	$r=1.448$	$x=1.840$

$$z=1.84\sqrt{1+\left(\frac{1.448}{1.84}\right)^2}=2.34$$

$$W_{2max}=\frac{E_p^2/2}{z+r+2bx_1(z+r_2)}$$

$$=\frac{(415)^2/2}{2.34+1.45+2\times0.046(2.34+0.208)}=21.2\text{ kw}$$

The asynchronous transmission capacity of the motor, as represented by W_{2max} calculated in accordance with the preceding formula, is used here to denote the maximum output which the motor is capable of developing when it has been connected to a given point in a given power supply system.

The transmission capacity thus defined does not, however, represent the continuous output rating, which will depend on the temperature rise in the motor, but will determine the ability of the motor to handle peak loads.

When designing the combination of motor and low-voltage supply line, one might be tempted to apply the conventional method of assuming a permissible voltage drop as a basis for the calculations. The danger inherent in this method of an assumed permissible voltage drop, which is based on the mean one-hour output, is that the power developed may be found inadequate at the still lower voltage occasioned by load peaks.

Conversely, the method of assuming a certain permissible voltage drop for the instantaneous peak load value may lead to overdimensioning of the motor line, which consequently becomes unnecessarily expensive.

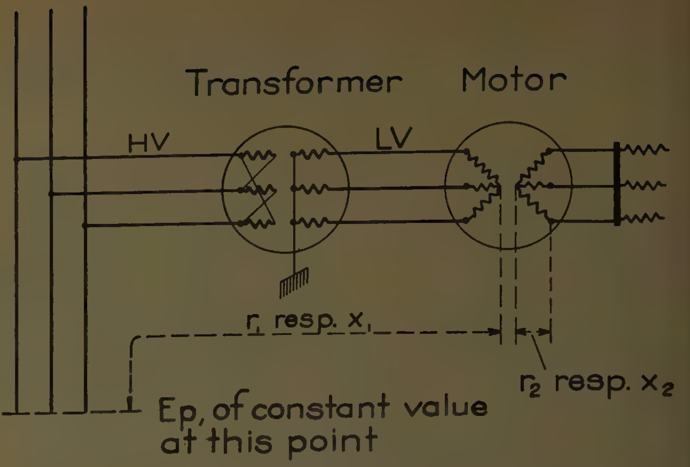

Figure 2. Wiring diagram for the transmission system consisting of a high-voltage supply, 50-kva transformer, low-voltage supply, and 30-horsepower motor used to obtain curve 2 of Figure 1

In those cases where the voltage drop itself is of minor importance it is therefore possible to select motor and cable such that W_{2max} as calculated by the method described will be adequate, the actual value of W_{2max} required for each case to be decided on the basis of practical experience.

A practical application of this approach to the problem is that of rural electrification in Sweden, where, to quote a case in point, it is usually desirable to make use of electric power for threshing. The mean one-hour output of a threshing motor is comparatively low, 10 to 15 kw, but the W_{2max} value must be in the region of 20 to 22 kw. As threshing is carried out over a short period of the year, fluctuations of the electric lights during working hours are no serious inconvenience, nor are the comparatively high transmission losses quoted very significant, as in the majority of cases the threshing barns will be located much closer to the transformer station than in the given example.

Measurement of Rate Drift of Timepieces

An instrument which provides a convenient graphic record of the drift in rate of a timepiece or an oscillator over an interval of several days has been developed by H. A. Bowman of the National Bureau of Standards. A simple relay-type servo system keeps the phase of a crystal-controlled standard frequency in step with the frequency of the timepiece. The amount by which the phase of the standard frequency must be shifted to match the unknown, varying frequency is then automatically plotted against time, providing a curve from which both the instantaneous and integrated frequency error are obtained. The displacement of this curve from a fixed reference line gives the integrated time error of the oscillator at any instant. The instantaneous frequency error is a function of the angle between this reference line and the tangent to the curve.

Measuring Water Velocity by an Ultrasonic Method

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MEMBER AIEE

IT IS DESIRABLE that the water discharged through the turbine of a hydroelectric unit be measured accurately under various conditions of loading, so that basic data may be obtained which will permit operating the unit at all times to extract the maximum power from the available water. There are numerous low-head hydroelectric developments which have short intake conduits carrying large quantities of water to the turbines. There is need for an improved method of measuring the water discharged through units in such stations because the precision of some existing and accepted methods is impaired by an intake of short length and some of the methods require the installation of equipment whose cost is often prohibitive. Further, some of the methods can measure turbine discharge only under special conditions which interfere with normal operation of the plant. Turbulence is sometimes another source of difficulty.

This situation has provided the incentive to search for an improved method of measuring large quantities of water. An ultrasonic method is being developed which promises to require the installation of only relatively simple testing equipment in the water intakes without interference to the free flow of water. The precision of the method does not appear to be affected by turbulent flow and ultrasonic testing probably will not interfere appreciably with the use of a unit for supplying power to the electric system load.

Figure 1 shows the principle of the method. Two transducer rods are placed in the duct in which measurement of water velocity is to be made. A transducer, when acting as the transmitter, converts high-frequency alternating current into mechanical vibrations of the same frequency. Conversely, mechanical vibrations picked up by a transducer are converted into alternating current. With the arrangement shown in Figure 1, it is found that the magnitude of the phase angle between the transmitted and received signal is a measure of the average velocity of the water passing through the duct. In practice, to avoid the necessity of measuring the phase angle with the water stationary, two phase-angle measurements are made in quick succession: first, with the downstream transducer receiving the signal of the upstream transducer, and second, with the functions of the two transducers interchanged.

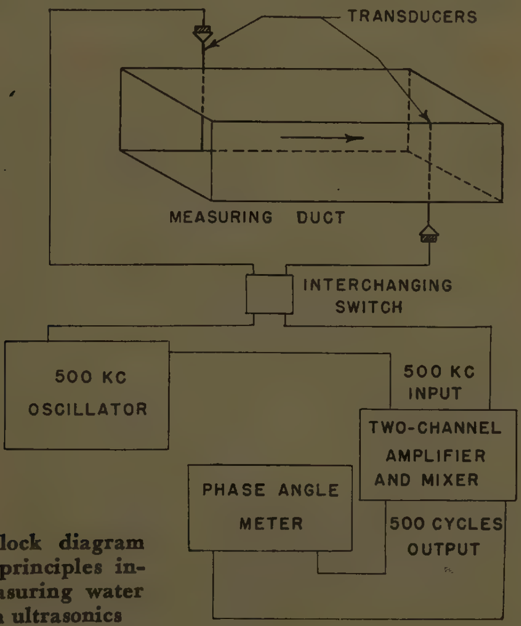

Figure 1. Block diagram showing the principles involved in measuring water velocity with ultrasonics

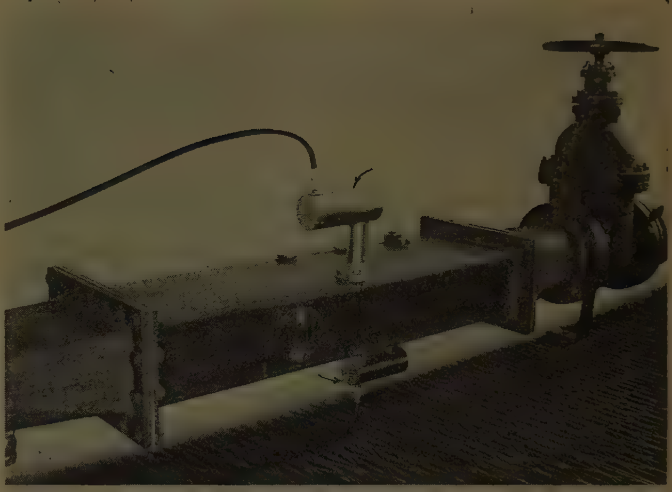

Figure 2. Test duct (arrows indicate transducer assemblies)

As represented in the diagram, part of the signal from the oscillator passes through one channel of the amplifier and mixer to the phase-angle meter. The signal from the receiving transducer passes to the phase-angle meter through the second channel of the amplifier and mixer. The beat method of reducing frequency maintains the phase relationship of the two signals.

The development of the ultrasonic method has progressed to the stage where water velocity measurements are being made in a small duct, five inches high by nine inches across (see Figure 2). The water velocities in the test section are up to six feet per second. The maximum error in tests has been two per cent with the average one per cent.

The development is still going on: therefore, this must be considered only as a progress report with the ultimate objective being a better method of measuring the discharge of large hydroelectric units in low-head plants having relatively short intakes. However, in its present stage of development, the method may prove useful in applications other than that for which it is being developed.

Digest of paper 50-214, "An Ultrasonic Method for Measuring Water Velocity," recommended by the AIEE Committees on Instruments and Measurements and Power Generation and approved by the AIEE Technical Program Committee for presentation at the AIEE Middle Eastern District Meeting, Baltimore, Md., October 3–5, 1950. Not scheduled for publication in AIEE *Transactions*.

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Long-Distance Power Transmission

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Many conclusions, which may guide new system design, can be drawn from recent studies of the performance of long-distance transmission systems. These studies were made on lines 600 miles long and cover both lines which had intermediate generation as well as those without.

MANY STUDIES have been made recently to determine the performance characteristics of long-distance transmission systems. This particular analysis considered straightaway transmission systems of 600 miles in length, a distance which is representative of transmission now under study and in actual development.[1,3] The system characteristics and requirements for economic transmission outlined here may be used to guide the future development of long-distance as well as moderate-distance transmission systems.

The first section of the article is devoted to straightaway transmission as far as 600 miles and considers the effect of intermediate switching stations, series capacitor compensation, intermediate synchronous condenser and shunt capacitor compensation, fault switching times, excitation system characteristics, generator and receiving system reactances, and inertias.

The second section gives consideration to 600-mile-long lines having intermediate generation. Power transmission systems 600 miles long use intermediate generation as a point for interconnection.[1,2] To determine the effect of intermediate generation on the over-all transmission of power it was assumed that this generation or system capacity existed at the half-way point. Several general conclusions can be drawn which may be used to indicate an expected trend in the development of such long-distance transmission systems.

RESULTS OF THE ANALYSIS

FROM the results of this analysis of 600-mile transmission the following conclusions have been drawn. The first two conclusions are a reaffirmation of previous studies.[2,4–6]

1. Intermediate switching stations constitute a very effective and practical way to increase the transmission-line loadings and reduce the cost of transmission.

2. Special means to overcome the stability limitations (commonly called compensation means) are also necessary to reduce the cost of long-distance straightaway transmission.

3. Series capacitors may be used as a basis for evaluating the expected cost of long-distance transmission.

4. Other methods of compensation, such as intermediate synchronous condensers and controlled shunt capacitors, may be comparable in cost to series capacitors. Their application will depend upon the amount of intermediate loading on the system under consideration.

5. Interconnection to intermediate system capacity is a practical and economical method to increase the power limits of long-distance transmission systems. When such intermediate capacity already exists this may constitute the most economical method of attaining low transmission costs.

6. A measure of the transmission system economy is the design loading of the circuits. There no longer appears to be any justification for design or maximum loadings below the surge impedance loading for any circuit, even if 600-mile-long circuits are required to withstand the loss of any one transmission-line section.

7. The higher voltages, 287 kv and 360 kv, with their high kilowatt loadings for optimum economy, essentially will be limited in their use for delivery of power to large integrated systems capable of absorbing large blocks of power, such as 400 to 800 megawatts per pair of circuits (see Table I).

8. With the continued growth, development, and interconnection of electric systems, the ability to absorb large blocks of transmitted energy is increasing.

9. Comparisons of a-c transmission with other methods of transmitting energy long distances should be persistently reappraised in view of the continued progress in the transmission art and the development of electric systems.

TRANSMISSION WITHOUT INTERMEDIATE GENERATION

Comparison of 200-Mile and 600-Mile Straightaway Transmission-System Power Limits. Figure 2 gives the results of differential analyzer studies of the power limit of 200-mile (Figure 2*A*) and 600-mile (Figure 2*B*) transmission sys-

Table I. Per Unit Bases Used in Calculation of Line Performance

Circuit (Kilovolts)	Per Unit Kilowatts* and Kilovolt-Amperes [5 (Kv)^2]
360	650,000**
287	412,000
230	264,000
161	130,000
115	66,000
69	24,000

* This column corresponds to the total surge impedance kilowatt loading of two circuits when each circuit has a surge impedance of 400 ohms.

** If a dual conductor[1,8] is used, the per unit power is increased approximately 25 per cent above the values shown so that at 360 kv the per unit power becomes 813,000 kw.

Essentially full text of paper **50-135**, "Long-Distance Power Transmission," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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tems. These studies were made for a double-circuit system with an intermediate switching station every 100 miles. The system shown in Figure 1 is the same as that used to obtain the data for Figures 2 and 8 with the following exceptions: to obtain the data for Figure 2*A* the transmission was limited to 200 rather than 600 miles, and the series capacitors (shown dotted) were used only for the data of Figure 8. The results of Figure 2 are for an uncompensated line; $x_c=0$. The differential analyzer method of analysis is described in reference 7. Figure 2 shows the effect of fault clearing time on the power limit, where the power limit is given in per unit sending-end power on a 5-kv² base. For example, per unit power for a 287-kv system is $5\times(287)^2$ or 412,000 kw. See Table I.

The results shown can be interpreted directly for any circuit with a single conductor per phase from Table I, which gives the per unit power and kilovolt-amperage for the higher voltages. If dual conductors are used, the per unit power and kilovolt-amperage will be increased approximately 25 per cent.[8]

As shown in Figure 2*A*, for the 200-mile line the power limit for 0.06-second fault clearing time and an exciter time constant of 0.68 second (per unit response of approximately unity) is 1.065 per unit or 440,000 kw for a 287-kv system. (That is, 692,000 kw for a 360-kv system and 866,000 kw for a 360-kv system with dual conductors.) This represents fairly good loading for a double-circuit 200-mile system. Figure 2*B* shows that the 600-mile uncompensated line ($x_c=0$), with the same amount of connected generation as for the 200-miles ystem, has a power limit equal to 0.735 per unit or 303,000 kw for 287-kv system. Therefore, the 600-mile line has a power limit of only 69 per cent of the 200-mile line, other conditions being kept constant. It should be noted that this comparison is on the basis of the same sending-end reactance for each case, or for the same equivalent generation.

If the generation had been reduced correspondingly to the reduced limit for the 600-mile case, in order to maintain the same per unit reactance per kilovolt-ampere of generat-

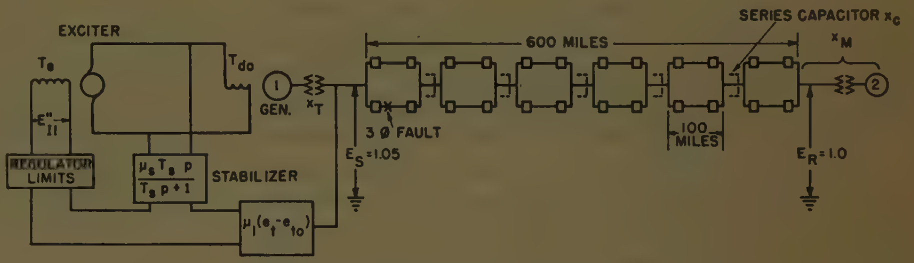

Figure 1. 600-mile transmission system. All quantities expressed in per unit are on a base of 5 (kv)². For a 287-kv transmission system this corresponds to 412,000 kw and 412,000 kva. The system constants are

Generator:	$x_d=0.63$ *per unit*	$x_d'=0.21$ *per unit*	$T_{do}=5$ *seconds*
	$x_q=0.42$ *per unit*	$H_g=5$ *seconds*	
Transformer:	$x=0.10$ *per unit*		
Line:	$x=0.8$ *ohm per mile per line*		$r=0.12$ *ohm per mile per line*
	$y=5.2\times10^{-6}$ *mho per mile per line*		
System:	$x_m=0.2$ *per unit (includes receiving-end transformer reactance)*		$H_2=50$ *seconds*
Regulating System:	$\mu_1=20$		$E''_{max}=+2.25$ *per unit, regulator*
	$\mu_2=4$		$E''_{min}=-0.30$ *per unit, limits*
	$T_s=0.47$ *second for 200-mile line*		$T_s=0.93$ *for 600-mile line*

System Damping:	Torque Coefficients	Fault On	Fault Cleared
	T_{d11}	1	4
	T_{d12}	0	3
	T_{d21}	0	3
	T_{d22}	15	18

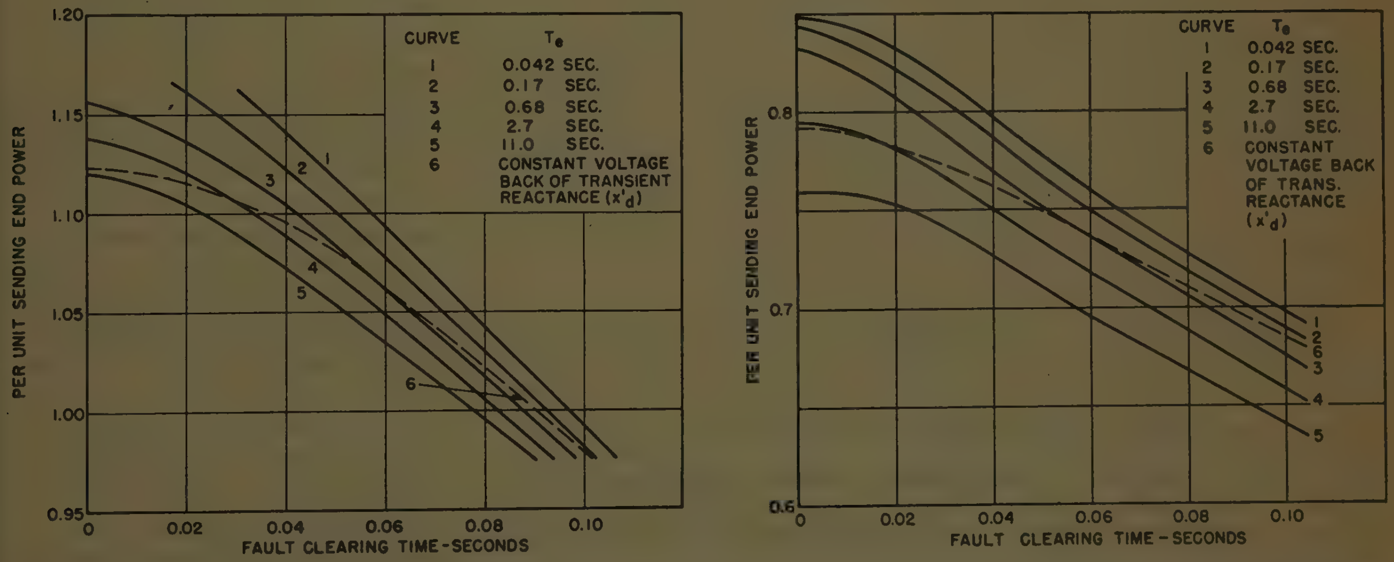

Figure 2. Sending-end power versus fault clearing time for stability with 3-phase fault at sending end showing the effect excitation system time constant with a switching station every 100 miles. A (left). 200-mile line. B (right). 600-mile line system of Figure 1

ing capacity, the power limit difference between 200- and 600-mile lines would have been increased. In making this study, the per unit generator power is assumed to be 5 kv^2, which is about the economical loading for a 600-mile double-circuit line (single conductor per phase) corresponding to 1.0 per unit power generation.

Effect of Intermediate Switching Stations. In the foregoing comparison of 200- and 600-mile transmission, the results are presented for the case of using intermediate switching stations every 100 miles, as this was considered the most economical number of intermediate switching stations.

Figure 3 shows how the power limit increases with an increasing number of switching stations. For this case the system shown in Figure 5 was used, assuming an equivalent voltage behind transient reactance x_d' and a total fault duration of three cycles. It can be seen readily that for the case of the 600-mile line the number of intermediate stations appreciably increases the power limit. The power limit more than doubles when five intermediate switching stations are used instead of none, and the received power limit is increased from 0.30 to 0.65 per unit, or from 124,000 to 268,000 kw, for a 287-kv system.

Assume that the transmission line costs $30,000 per circuit mile for a 287-kv system, $36,000,000 for the two circuits; and the transmission-line circuit-breaker positions cost $200,000 per switch position, a total of $800,000 for four circuit breakers when no intermediate stations are used and $4,800,000 for 24 circuit breakers when five intermediate stations are used. Then the cost per kilowatt for the transmission, not including the terminal transformers and their circuit breakers, is

$$\frac{36{,}800{,}000}{124{,}000} = \$297 \text{ per kilowatt, no intermediate switching stations}$$

$$\frac{40{,}800{,}000}{268{,}000} = \$152 \text{ per kilowatt, five intermediate switching stations}$$

This result is not surprising, as it is well known that the use of intermediate switching stations is an economical means to increase the reliable power limit of high-voltage transmission systems.[2,6] In this study intermediate stations were assumed to be spaced every 100 miles.

Series Capacitor Compensation. Figure 4 shows the increase in transient power limit with increased series capacitor compensation. Per cent series compensation is taken in this article to mean the per cent compensation of the reactance of the line; that is, for a 600-mile double-circuit line with 0.8 ohm reactance per mile, 75 per cent compensation distributed in five intermediate stations is

$$x_c = \frac{600\times 0.8\times 0.75}{2\times 5} = 36 \text{ ohms per phase per station or 0.18 per unit on a base of } 5\text{ kv}^2$$

Figure 5 is the system studied for this case. At 75 per cent line compensation, the sending-end power is 1.10 per unit power, and the receiving-end power is 0.98 per unit power. A 75-per cent compensation of the line, therefore, results in practically 1.0 per unit power transfer. For a 287-kv system this is $0.98\times 412{,}000 = 403{,}000$ kw.

Previous studies[5,9] have indicated that systems may be built with as much as 75-per cent compensation and satisfactory operation can be expected. Line compensation of 75 per cent for this system at 287 kv requires about 0.90 per unit capacitive kilovolt-amperes in series capacitors and 0.90 per unit reactive kilovolt-amperes in shunt reactors or 370,000 kilovolt-amperes of each. If the series capacitor and shunt reactor compensation is assumed to cost a total of $12 for each capacitive kilovolt-ampere plus each reactive kilovolt-ampere, the compensation for a 287-kv line is 370,000 × $12, or about $4,500,000. Using the previous example, the cost for transmission with five intermediate switching stations (excluding the terminal transformers and their circuit breakers) plus the compensation, is $40,800,000 plus $4,500,000, or $45,300,000. The received power limit is increased from 268,000 kw to 403,000 kw. The cost per kilowatt is reduced accordingly from $152 to $112. This figure of $112 per kilowatt can be used in comparison with other methods of increasing the power limit. Studies of this system with series capacitors were made also without shunt reactors.

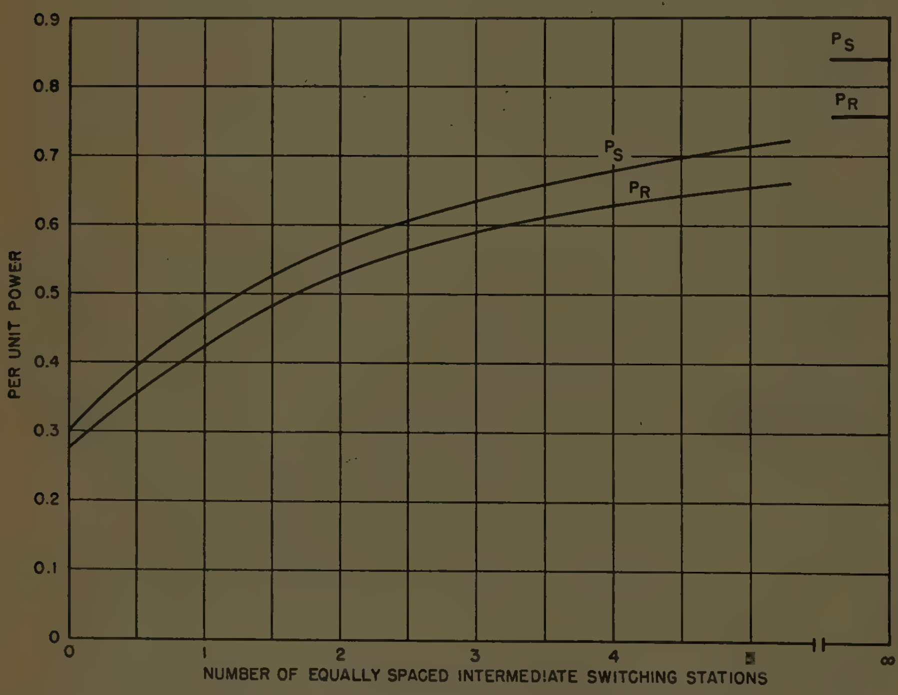

Figure 3. Effect of intermediate switching station on transient stability limit for 600-mile transmission system similar to that of Figure 5 except that the number of intermediate switching stations was varied and series and shunt compensation was not used

$V_R = V_S = 1.0$ $H_g = 5.0$ $H_m = \infty$ $x_g = 0.30$ $x_m = 0.25$

Per unit power and kva $= (5\text{kv})^2$ *Fault clearing time* $= 0.05$ *second*

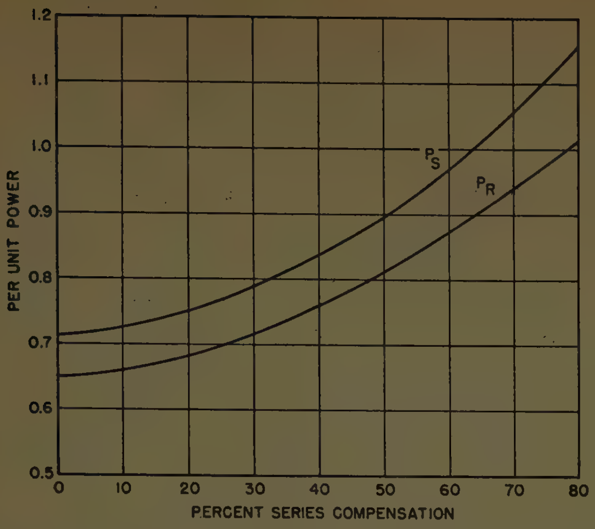

Figure 4. Transient stability limit of 600-mile line with the per unit power generated and received as a function of per unit series capacitor compensation. There are five intermediate switching stations. See Figure 5 for the system

$V_S=1.05$ $V_R=0.95$ $x_g=0.30$ $H_g=5.0$ $x_m=0.25$ $H_m=\infty$

Per unit power and kva=5 (kv)². The shunt reactor compensation equals the series capacitor compensation so that at normal frequency the surge impedance of the compensated line is 400 ohms. Fault clearing time=0.05 second. Capacitor reinsertion time assumed to be zero

Figure 6 is a summary of a differential analyzer study which shows the variation in power limit in per unit as a function of switching time and exciter time constant for a 600-mile line (system of Figure 1) with 75-per cent series capacitor compensation without the use of shunt reactor compensation.

When Figure 6 and Figure 2*B* are compared, a good comparison is obtained of the effect of series capacitor compensation, as all of the other system characteristics (Figure 1) were kept constant except for a change in voltage regulator stabilizer time constant T_s. The sending-end power limit for a fault-clearing time of 0.06 second and an exciter time constant of $T_e=0.68$ second has been increased from P_S of 0.735 to 1.07. The latter value is practically the limit obtained for the same conditions for a 200-mile uncompensated line, Figure 2*A*. In other words, the effect of 75-per cent series capacitor compensation has, in effect, increased the power limit of the 600-mile line to that of an uncompensated 200-mile line.

Intermediate Synchronous Condenser Compensation. A study of the effect of intermediate synchronous condenser capacity was made to determine the effectiveness of this method in increasing the power limits of the 600-mile system. Previous steady-state stability studies[10] have indicated the desirability of keeping the transient reactance of the intermediate synchronous condenser as low as practicable and distributing the synchronous condenser capacity along the line. The present transient stability study of the 600-mile-line case also showed the desirability of keeping the reactance as low as practicable and distributing the available capacity at more than one intermediate location. The optimum distribution for the transient case is dependent, among other factors, on the location of the faulted line section. For example, if an intermediate synchronous condenser is placed at the mid-point of the system of Figure 5, having a per unit rating of 1.25 and a transient reactance including its high-voltage transformers of 0.25 on its own rating, the sending power limit is increased from 0.71 per unit ($x_g=0.30$) to 0.90. Whereas, if the same condenser capacity is equally distributed at the five intermediate stations, the sending-end power limit is increased to 0.98. If the synchronous condensers were distributed to obtain the highest power limit for a given system, the received power limit would be still further increased to at least 1.03 for this particular amount of synchronous-condenser capacity.

If the system has intermediate loads requiring synchronous-condenser voltage and reactive kilovolt-ampere control at intermediate points, then the benefits of the synchronous condenser are increased.

Intermediate Shunt Reactive Control Using Static Capacitors. Consideration has also been given to the possibilities of using intermediate controlled shunt reactive kilovolt-amperes for increasing the power limits. Dr. E. F. W. Alexanderson has proposed the use of arrangements of reactors and capacitors to obtain voltage control whereby the correction can be applied smoothly rather than in large increments.[11]

Consideration of such schemes indicates that, if the intermediate correction is distributed, higher power limits are obtained for a given total corrective capacity. Typical of the results are those shown in Figure 7 which were obtained with control only at the mid-point. With this the sending-end power limit may be increased from 0.71 to 0.95 per unit with a total resultant capacitive corrective kilovolt-amperage of 0.5 per unit. For a 287-kv system this corresponds to a capacitive kilovolt-amperage of 206,000 and a reactive kilovolt-amperage of 412,000 if the resultant capacitive kilovolt-amperage is to be controlled by variation of the reactive kilovolt-amperage. Here it was assumed that equal amounts of lagging and leading kilovolt-amperes were available at the mid-point and that they were applied instantaneously and smoothly to obtain a change in corrective current up to the limit

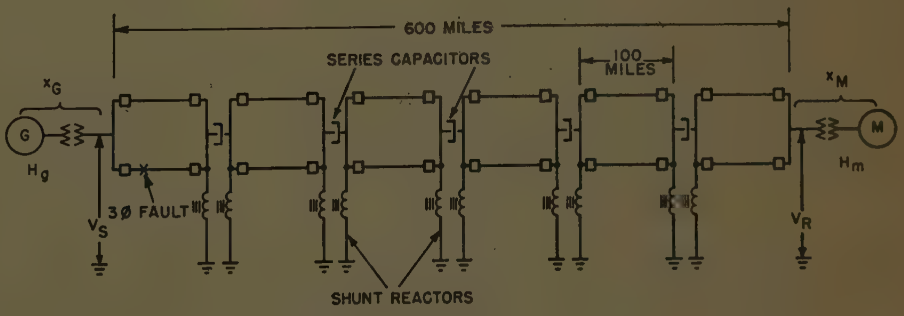

Figure 5. System diagram showing series capacitor compensation

of the capacity assumed for each case, with a regulation characteristic of 0.20 per unit for each 0.01 per unit deviation from normal voltage.

600-MILE TRANSMISSION WITH MID-POINT GENERATION

THE SYSTEMS studied are shown in Figure 8. Figure 8*A* shows the system which may be considered the initial development of a transmission system with a generating station 300 miles from its load center with three transmission lines and two intermediate switching stations. Figure 8*B* shows the same system but with another generating station located 600 miles from the load center and interconnected into the transmission system at the first generating station. From a study of the system of Figure 8*A*, it is found for the reactances chosen that the power limit of the sending-end power for a 3-phase fault near the sending-end bus of a duration of four cycles is 1.33 per unit; on the kilowatt base of $5\ \text{kv}^2$, for a 287-kv system, this is 550,000 kw.

The effects of variation in the receiving-end reactance were also studied. The power limit was reduced almost 15 per cent by a 100-per cent increase of the receiving-end reactance. It is significant that the receiving-end reactance is quite important in determining the maximum power transfer and that in the design of a system for receiving large blocks of power from distant stations it is essential for good economy to keep this receiving-end equivalent reactance as low as is practical by a rational circuit arrangement. It becomes particularly effective to bus all high-voltage circuits near the receiving end directly together. Fortunately this can now be more readily accomplished with the development and increasing use of high interrupting capacity circuit breakers.[12]

Keeping the output of the mid-station generator Number 1 at 1.33 per unit, corresponding to its maximum power limit with three lines, the system of Figure 8*B* was analyzed to determine the maximum total sending-end power that could be transmitted with stability. This limit was found to be 1.73 with 1.33 from generator Number 1 and 0.4 from generator Number 2. This corresponds to a loading on the two circuits from the distant generating point of 160,000 kw for a 287-kw system. The total received power P_R for this case is $1.62\times5.0\times(287)^2=666,000$ kw. As this is a relatively light loading, the problem was studied to obtain an increase in the loading, particularly from the distant station.

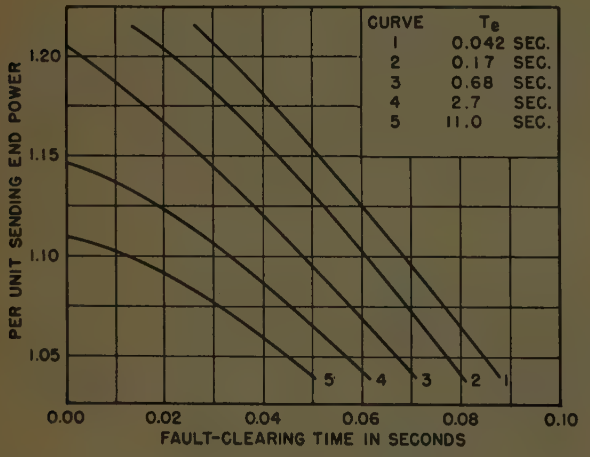

Figure 6. Transient power limit for 600-mile 75-per cent series compensated line. System conditions are the same as Figure 1 except the capacitors shown dotted in Figure 1 are assumed in the circuit. At each intermediate switching station $x_c=-0.18$

If the mid-station reactance is halved and the inertia is doubled, in effect corresponding to interconnecting to a moderate amount of system capacity at this point, see Figure 8*C*, the power limit for the distant generating station is increased from 0.4 per unit to 0.85 per unit. If the mid-station reactance is further reduced to one-third of its original value and its inertia trebled, the power limit for the distant generating station is increased to 0.9. At this loading the critical fault moves from location Number 1 at the mid-station to location Number 2 at the distant generating station. With this doubling or trebling of the equivalent capacity at the mid-point, the power limits of the system approach those which may be considered reasonable from an economic standpoint. For a 287-kv system the mid-generating station remains at 550,000 kw, and the output of the distant station is 370,000 kw. It is estimated that the loadings shown in Figure 8*C* would be realized if the tie is made to generating capacity of twice that of generator Number 1 and with an autotransformer bank capacity of about 300,000 kva for a 287-kv system. The additional power delivered to the load from the 600-mile-distant source of the system shown in Figure 8*C* as compared with the system of Figure 8*A* is 0.76 per unit. This was obtained by adding 900 circuit miles of line, approximately 22 circuit breaker positions, and a 300,000-kva autotransformer bank.

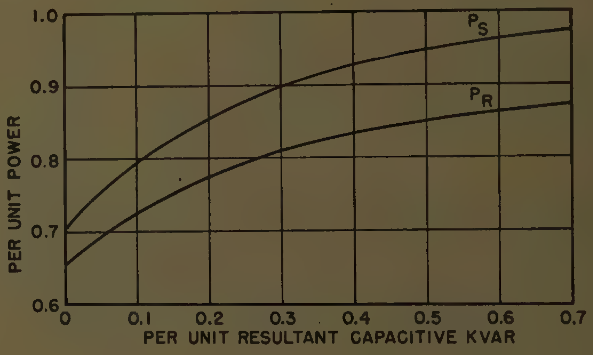

Figure 7. Transient power limit for 600-mile line using controlled capacitors and reactors at the mid-point switching station. The system consists of five intermediate switching stations similar to that of Figure 5. Corrective reactive kilovolt amperes of 0.20 per unit is applied for each 0.01 per unit of voltage variation from unit voltage at the mid-point. The total resultant reactive kilovolt-amperes are equal to the capacitive kilovolt-amperes shown on the abscissa

$H_g=4.0$ $x_g=0.30$ $x_m=0.25$ $H_m=\infty$ $V_R=V_S=1.0$

Base kilowatts = base reactive kilovolt-amperes

Assuming again a 287-kv system, the additional power delivery is 315,000 kw. The cost of the additional transmission circuits at $30,000 per mile is $27,000,000; the 22 circuit breakers at $200,000 per position are $4,400,000;

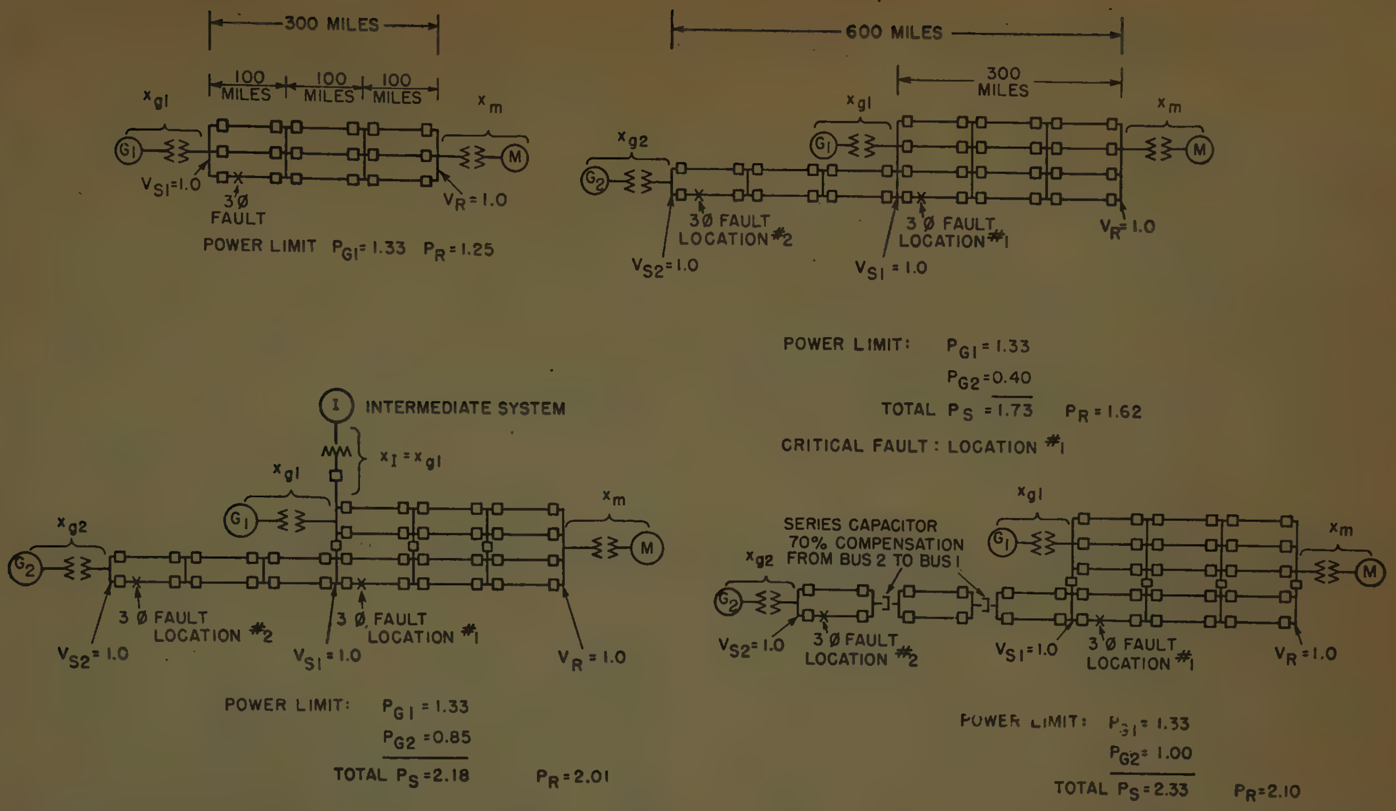
300 MILES
100 MILES
100 MILES
100 MILES
x_{g1}
x_m
G1
M
V_{S1}=1.0
3Ø FAULT
V_R = 1.0
POWER LIMIT P_{G1}= 1.33 P_R = 1.25
600 MILES
300 MILES
x_{g2}
G2
3Ø FAULT LOCATION #2
3 Ø FAULT LOCATION #1
V_{S2}=1.0
V_{S1} = 1.0
POWER LIMIT: P_{G1}= 1.33
P_{G2}=0.40
TOTAL P_S =1.73 P_R = 1.62
CRITICAL FAULT : LOCATION #1
I
INTERMEDIATE SYSTEM
$x_I = x_{g1}$
POWER LIMIT: P_{G1} = 1.33
P_{G2} =0.85
TOTAL P_S =2.18 P_R =2.01
SERIES CAPACITOR 70% COMPENSATION FROM BUS 2 TO BUS 1
POWER LIMIT: P_{G1}= 1.33
P_{G2}= 1.00
TOTAL P_S =2.33 P_R=2.10

Figure 8. Transmission systems studied to determine the effect of mid-point generation. A (upper left): Initial system development. B (upper right): Initial system development plus extension of system for transmission of power from 600-mile-distant source. C (lower left): System B with intermediate system interconnection assumed equivalent to halving x_{g1} and doubling H_{g1}. D (lower right): System using series capacitors and additional 300-mile circuit added to that used by system B

Base kw = Base kva = 5 (kv)²

Generators:	*(Generator kilovolt-ampere rating assumed equal to kilowatt output at stability limit.)* $x_{g1}=0.30$ *on kva rating* $x_{g2}=0.30$ *on kva rating*		$H_{g1}=5.0$ *on kva rating (seconds)* $H_{g2}=5.0$ *on kva rating (seconds)*
Line:	$x=0.8$ *ohm per mile*	$r=0.08$ *ohm per mile*	$y=5.2$ *micromhos per mile*
Receiving-end System:	$X_M=\dfrac{0.50}{\text{number of receiving-end circuits}}$		$H_M=\infty$
Fault:	*Three-phase, 0.067 second or 4 cycles*		

the autotransformer bank installed at $3.00 per through kilovolt-ampere installed is $900,000, or a total of $32,000,000. This is power transferred at 32,300,000/315,000 = $101 per kw. This figure, although only approximately obtained, indicates that the connection to intermediate system capacity when possible compares quite favorably with the straightaway compensated transmission cases previously considered and may result in the most economical transmission system.

It may be concluded here that a system of substantial line loadings per circuit can be realized even for 600 miles, if the high-tension lines are tied directly together and full use is made of the line generation or system capacity of two to four times the capacity of the distant generator source. It should be kept in mind that intermediate switching stations and a low-reactance receiving system are also necessary. The important conclusion is that by rational system design heavy line loadings are realizable at relatively small increase in cost, resulting in important reductions in the cost per kilowatt for transmission.

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Electrostatic Storage Tube

S. H. DODD H. KLEMPERER P. YOUTZ

A beam-deflection electrostatic tube has been developed to store binary-coded information at two stable potential levels, 100 volts apart, for digital computers or communications systems. A single 2,000-volt electron beam writes or reads one of 400 binary digits on a 4-inch target. A 100-volt electron flood replaces leakage and retains stored information indefinitely. The potential boundary stability on the storage surface is assured by a mosaic of conducting beryllium squares.

ALL COMPUTING machines and information-processing devices require some type of storage. Analogue computers have information storage scattered through the machine as part of the computing elements. For example, an electronic analogue computer might have a simple resistance-inductance-capacitance computing circuit whose basic storage would be twofold. The instructions for the type of computation would be stored in the interconnections of the resistance, inductance, and capacitance components. The initial conditions and partial and final results would be stored as current and voltage in the components of the computer.

In the high-speed automatic digital computer[1] the storage function is distinct from the computing function. The digital computer consists of five elements, an arithmetic element that does the actual computing, a storage system that stores instructions and intermediate results, a control that directs the carrying out of the instructions, and input and output elements that insert data and extract results. The flexibility of the digital computer results from separation of the storage and computing functions. Operation of storage and the arithmetic element on a time-sharing basis allows information to be removed from storage, acted upon by the arithmetic element, and replaced in storage, in a sequence describing the problem being solved.

A digital computer uses a large number of identical storage elements which can be used in one problem to store instructions for the process the machine should follow, while in another problem they might be used for storage of partial results or of initial data. Most digital computers use binary-coded information. Storage systems for these computers are usually one-fourth of the size of the entire machine, and thus they strongly influence the entire design of the machine.

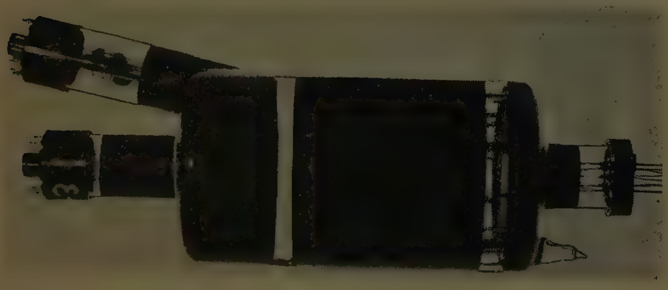

Figure 1. The Massachusetts Institute of Technology electrostatic storage tube. This memory element of a computer will store 256 to 1,024 bits of information indefinitely. Access to any bit can be gained within 6 to 25 microseconds, which includes all the operations necessary for locating and reading or writing this information

The fundamental storage problem is not so much that of discovering an element which will retain information; it is the far more difficult problem of switching or selecting among the large numbers of individual elements which make up the storage system. A possibility used in many computer designs is to store a sequence of digits in a delay line or on a magnetic drum. A sensing element then selects among the digits in time as they pass by, while a second selection in space is made among a number of lines. Thus delay lines and magnetic drum storage make one co-ordinate selection in space and one in time. Using the time co-ordinate leads to a long access time and slow operation.

A second possibility is to store digits in a 2-dimensional spatial array in an electron tube where digits are stored as electric charge on a surface at the intersections of rows and columns. The two space co-ordinates can be selected rapidly and simultaneously by a low-inertia electron beam. Although higher in initial and operating costs than some other types of storage, the electrostatic storage tube is essential in computer applications which demand the highest speeds.

The Massachusetts Institute of Technology storage tube was developed for the Office of Naval Research to be used as a reliable high-speed memory device for a parallel-type digital computer.

Such storage media must be built to have the following characteristics:

1. Since each bit of information to be remembered has a binary representation, the device is required to store just two possible values for each digit—either a zero or a one. This requires two stable storage levels—one representing a zero, the other representing a one.

2. The device must be able to place a number in any of its storage positions quickly and without errors. This is called writing.

3. The device must be able to remove any number from

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any storage position quickly and without errors. This is called reading.

4. The device must hold the numbers in storage permanently without errors as long as power is supplied to the tube. This is called holding.

5. For parallel computer storage, the device must be adapted to selecting and reading a single digit so that a bank of tubes operating in parallel can simultaneously deliver the separate digits of a stored number.

CHARACTERISTICS OF THE TUBE

Physical Appearance and Description. Figure 1 shows the storage tube. It is a special cathode-ray tube in which both zeros and ones are stored as charges on a dielectric surface located at one end. Two electron guns are mounted at the other end. One of these is used to write and read, the other to hold the information. The write–read gun is an ordinary cathode-ray gun which is electrostatically focused and deflected. The deflection plates position a 50-microampere beam to a desired spot on the surface. Then the beam is used to charge the spot to one of the two desired charge levels. The holding gun, which is a triode structure, provides the holding action in the tube and permits permanent storage of information.

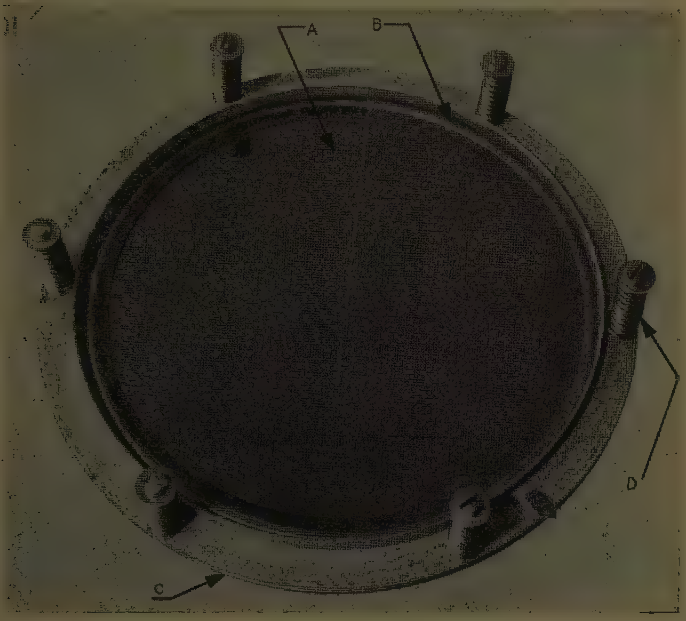

Figure 2. A close-up and cutaway front view of the storage assembly showing (A) the storage surface which is a beryllium mosaic on mica dielectric, (B) the collector screen, (C) the screen frame, and (D) tungsten spring

The storage assembly can be seen in Figure 2, which is a cutaway view of the 100-mesh wire collector screen and the 4-inch diameter dielectric plate. The storage assembly consists of the collector screen and the storage surface which is spaced 0.015 inch behind the collector. The storage surface consists of a mosaic of small squares of conducting material on the dielectric plate. A backing plate supports the dielectric and at the same time makes electrical contact with the silver film on its back surface. Two mica spacers insulate and locate these components within a frame. Tungsten springs are used in order to insure adequate screen tension.

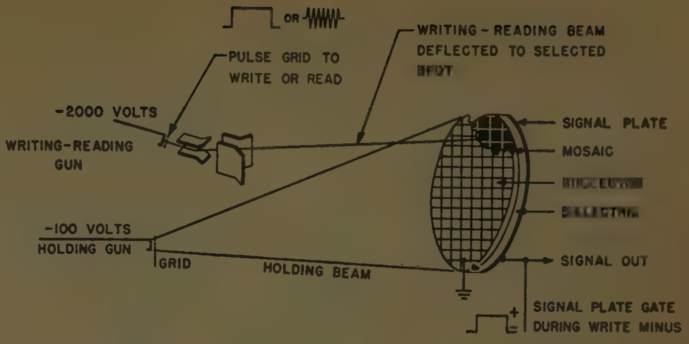

Figure 3. Schematic view of the MIT storage tube showing operational conditions and components

Performance. Information in the form of negative or positive signals is stored on the surface and read out at any desired moment. The time required for writing and reading is called the access time. The access time includes positioning the write–read beam to the desired storage location, turning on the beam, picking up capacitively the read-out signal from the signal plate, checking, and rewriting the stored signal when necessary. At present the access time of the tubes, including all these operations, ranges from 6 to 25 microseconds and a tube stores between 256 and 1,024 binary digits in the form of discrete positive or negative charges. The access time and density depend on the type of tube, the mode of operation, and the reliability which is required of the computer. At present, the lower storage densities give the high reliability required in a digital computer.

Tube life tests have been made in special life racks under both dynamic and static conditions. These tests indicate that the cathodes of the electron guns are the limiting factor in the life of the tubes. It is possible to replace the guns when they are deteriorated and reprocess the tubes. By this method the useful life can be extended several thousand hours. Six electrostatic tubes have already been life-tested between 5,000 and 8,000 hours with static patterns stored on them.

OPERATION

Introduction to Components and Terminology. Before the operation of the tube is discussed, reference should be made to the pictorial schematic of the components which are shown in Figure 3. The storage assembly consists of the following elements:

1. A collector made of 100-mesh-per-inch wire screen. This collector is held 0.015 inch in front of the storage surface. It serves as the collector and as the voltage reference level for the secondary electrons emitted from the storage surface.

2. The storage surface, which is a beryllium mosaic on mica. The conducting islands are carefully insulated from each other and have a high secondary emission yield. Further, these mosaic elements are small enough so that the

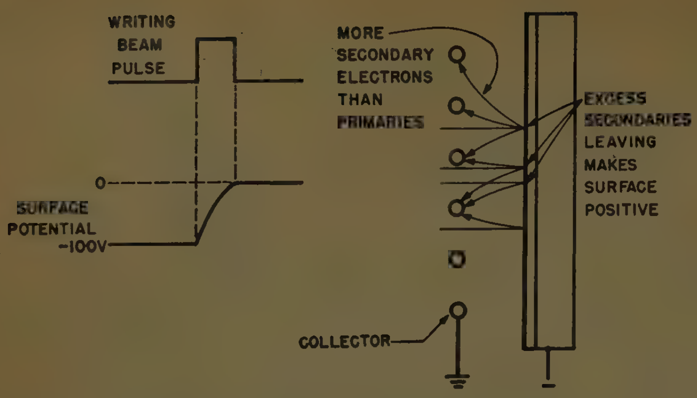
WRITING
BEAM
PULSE
MORE SECONDARY ELECTRONS THAN PRIMARIES
EXCESS SECONDARIES LEAVING MAKES SURFACE POSITIVE
0
SURFACE POTENTIAL
-100V
COLLECTOR

Figure 4. Conditions at storage surface during writing positive

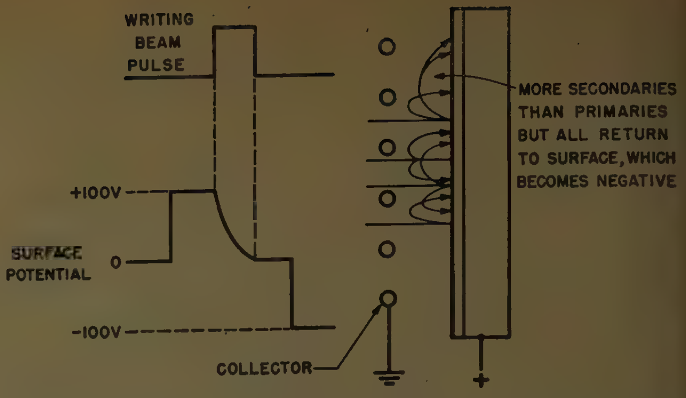
WRITING
BEAM
PULSE
MORE SECONDARIES THAN PRIMARIES BUT ALL RETURN TO SURFACE, WHICH BECOMES NEGATIVE
+100V
SURFACE POTENTIAL
0
-100V
COLLECTOR
+

Figure 5. Conditions at storage surface during writing negative

writing beam charges a number of them in writing one spot. Mosaic sizes of 40, 60, and 100 squares per linear inch have been used. The secondary emission properties of beryllium with a thin film of oxide make this material well suited to the application.

3. The dielectric, which is a 4-inch-diameter mica sheet 0.005-inch thick.

4. The signal plate, which is a film of silver on the back of the mica plate.

It should be noted that the collector is always at ground potential. The signal plate has positive potential during two operations—both in writing minus and in reading what has been stored in the tube.

Writing is simply the storing of a charge representing a zero or one at the selected spot on the storage surface. The ones are stored at the level of the collector potential and the zeros are stored at the level of the holding-gun cathode potential.

Reading is the examination of any selected spot and the production of a signal representing the zero or one digit which is stored.

Holding is the replenishing or depleting of the stored electrons to maintain each spot at the original value which was stored. This is accomplished by flooding the storage surface with a uniform beam of low-velocity electrons. Holding is required in order to control the effects of leakage and stray secondary electrons, and in some cases to renew the charge of the stored signal which is partially removed by reading.

Writing. To write on the storage surface, the high-velocity-gun deflection-plate voltages are established so that when the beam is turned on it will select the desired spot. The high-velocity beam covers from 10 to 25 mosaic squares, and it always charges them to the potential which is on.

Writing positive is illustrated in Figure 4. In order to write a positive spot, the high-velocity beam is simply biased on until it charges the spot to collector potential. If the spot was at collector potential before writing positive, it stays at collector potential. If the spot was at holding-gun-cathode potential before writing, it is charged to collector potential during writing. This is so because there will be more secondary electrons emitted from the spot than there are primaries attracted to it, and the excess secondaries leaving the spot will charge it positive until it reaches collector potential.

Writing negative is shown in Figure 5. When a negative spot is to be written, a positive gate of 100 volts is applied to the signal plate. This capacitively raises the level of the whole storage surface by almost 100 volts during the gate. While the surface is still 100 volts above normal the high-velocity beam is biased on and brings the storage spot to collector potential because a storage surface more positive than the collector screen will attract and return the secondary electrons to the surface. (The writing beam always charges an area to collector potential.) Thus the selected spot is established at ground regardless of its previous potential. The gate to the signal plate then terminates, and this spot on the surface drops 100 volts below ground. All other spots on the surface drop back to the potentials they held before the signal plate was gated.

Thus, if the high-velocity beam is biased on without gating the signal plate, the selected spot is written at ground potential; if the high-velocity beam is biased on while the signal plate is gated, the selected spot again is written at ground potential but then assumes holding-gun cathode potential when the signal-plate gate ends. This writing action is not dependent on the potential of the spot before the writing operation and therefore no erasure is required to store new information.

Reading. Now consider the method of reading. The writing operations produce an array of spots on the surface representing zeros and ones. The ones are spots at ground potential; the zeros are 100 volts below ground potential at the holding-gun cathode.

Reading detects both positive and negative areas. During the reading operation the high-velocity beam is deflected to the spot to be read and is used to change the charge on the spot. This change in charge is capacitively coupled to the signal plate, and the displacement current is detected as an output signal. Detecting both positive and negative charge levels requires gating the signal plate to a level intermediate between the two stable charge levels. The spot being read then charges or discharges to this intermediate level; the change in charge produces a positive or negative output signal accordingly.

In the MIT computer operation the high-velocity beam is radio-frequency intensity-modulated at ten megacycles during the reading operation so that a radio-frequency signal can be easily separated from the signal-plate gate. The radio-frequency signal is then amplified and detected in a phase-sensitive circuit, giving video output pulses of both polarities. Since pulses of both polarities are available, checking circuits can be designed to assure that a read-out actually occurs.

Various factors can cause a change in charge of the stored spots. One of these is leakage. To minimize this, the best possible dielectric is used and kept very clean during all handling and processing.

There are three other factors which disturb the charge stored on the surface:

1. The secondary electrons from bombardment of other spots on the storage surface.
2. The secondary electrons from the primary electrons striking the collector grid.
3. The reading beam itself.

Holding. To compensate for these disturbances and restore leaked charge, either regenerative or static holding may be employed. Regenerative holding has been described by F. C. Williams[2] in England; provision is made for rewriting every stored signal frequently so that the decay is not enough to destroy the identity of the stored signal. In contrast, the MIT tube uses static holding. Once a digit is written, it will be held indefinitely without any rewriting.

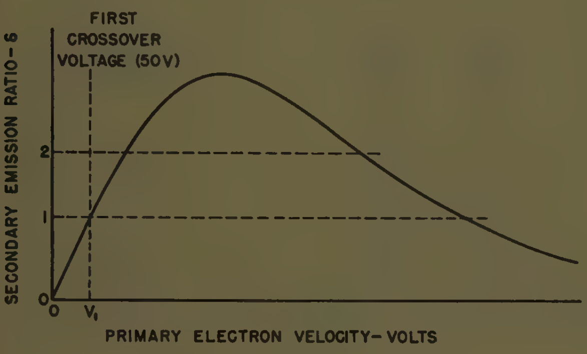

Figure 6. **A typical secondary emission curve gives the ratio of secondary to primary current as the velocity of the primary electron varies**

This static holding has been described in the literature of a number of authors, particularly J. A. Rajchman[3] and A. V. Haeff.[4] Mr. Rajchman used it in a memory tube which does not use a deflection system. Mr. Haeff used it in a beam-deflection electrostatic picture-storage tube. In the MIT tube, the holding gun floods the storage surface with a spray of 100-volt electrons to maintain the stored signals at their two stable potentials. The two stable potentials of the tube are the collector potential and the holding-gun cathode potential.

Figure 6 shows a typical secondary emission curve. It gives the ratio of secondary to primary current as the velocity of the primary electron varies. The curve shows that incoming electrons at low velocities release few secondaries but that as incoming electron velocity increases the ratio soon increases to the point where more secondaries than primaries are emitted. When electrons from the holding gun strike the target surface, they release from the target material electrons which are emitted at low velocity toward the collector screen. Only the velocity range below the peak of the curve is of interest in determining holding-gun action.

Negative Spot Holding. Figure 7 shows how the electrons behave when an area on the storage surface is near the negative stability point at holding-gun cathode potential. To show that actual stability exists, consider what happens when the surface is below or above the stability point. The left figure shows a surface below the holding-gun cathode potential. The holding-gun electrons arrive at the plane of the collector with 100 volts energy but will never reach the surface since it is more than 100 volts negative; thus no holding current flows to the surface. Small leakage currents to surrounding positive elements cause the surface to charge positive.

On the other hand, the figure on the right shows a surface slightly above cathode potential. The holding-gun electrons strike the surface with a few volts velocity. The secondary emission is less than one so there are more primary electrons arriving at the surface than there are secondaries leaving. The resulting accumulation of electrons charges the surface in a negative direction until it reaches holding-gun cathode potential.

At holding-gun cathode potential, only enough primary electrons strike the surface to supply the leakage current. Thus, if the surface differs from the negative stability point by a few volts in either direction, a restoring current returns the surface to the stable potential.

Positive Spot Holding. Figure 8 shows how the electrons

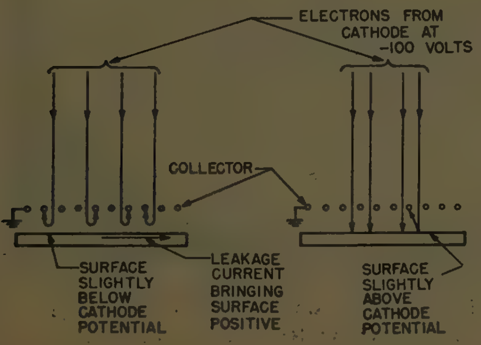

Figure 7 (left). Conditions on the storage surface for holding-gun operation near negative stability

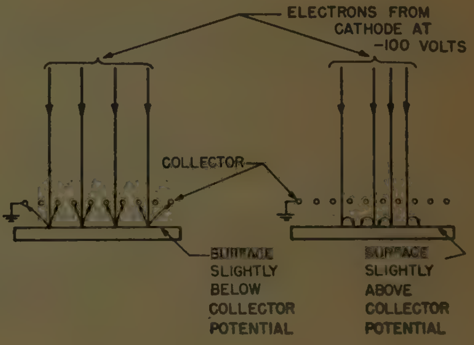

Figure 8 (right). Conditions on the storage surface for holding-gun operation near positive stability

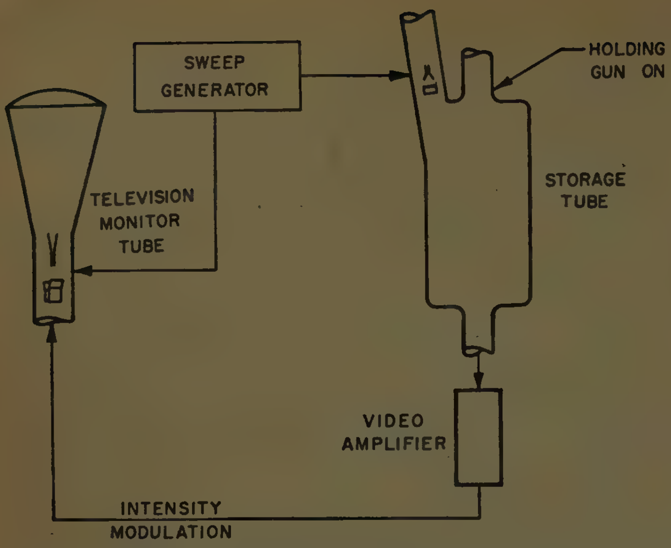

Figure 9. Block diagram of the setup used for television monitoring of charge distribution on the storage surface of a storage tube

behave when an area on the storage surface is near the positive stability point. The positive stability point is at collector potential so the holding gun electrons strike the surface with approximately 100 volts velocity. Therefore, the secondary emission ratio is about two. The left figure shows a surface slightly below collector potential. The secondary electrons are attracted to the collector and the net loss of electrons charges the area in a positive direction toward the collector.

The right figure shows a surface above collector potential. It is true that the secondary emission ratio is about two, but the positive surface attracts the secondaries. Thus both primary and secondary electrons accumulate at the surface and charge it negatively toward collector. A positive area is thus kept at collector potential and a disturbance of a few volts in either direction will result in a restoring current.

The important characteristics of the holding-gun operation are:

1. A stable negative spot cannot charge positive because low-energy holding electrons accumulate and few secondaries are released.
2. A stable positive spot stays positive because the excess of secondary electrons over primaries charges the surface positive to collector.

Mosaic Improves Stability. The mosaic improves the stability of the stored patterns, prevents migration of boundaries between positive and negative areas, and makes the holding gun more effective. The holding-beam current, falling uniformly over a conducting mosaic element, is able to counteract leakage from the edges of one island to a neighboring island. The mosaic size used is a compromise between adequate storage stability and high density of stored digits.

Larger mosaic islands give larger stabilizing current and higher storage stability. On the other hand, the mosaic size must be small enough for the surface to appear essentially continuous with respect to the definition of the writing and reading gun. Then the deflection system need be constructed to aim the beam during reading only at the written spot rather than at a previously determined physical area.

The beryllium mosaics are prepared in very high vacuum by sublimation through a wire mesh mask held tightly against the mica. The mosaic on mica is removed and assembled in a clean storage assembly.

TESTING METHODS

Figure 9 shows the block diagram of a test system designed to give a visual display of target potential distribution in a storage tube.

The sweep generator provides a television-type scan for both a monitor tube and the write–read gun of the storage tube. The beams in both of these tubes are deflected simultaneously.

The holding gun restores the charge lost during reading scans. The output signal from the storage tube, after amplification, is used to intensity-modulate the monitor tube. Thus, negatively stored areas will give a strong read-out signal resulting in a bright area on the monitor tube, while positively stored areas will result in dark areas on the monitor tube.

An array of positive spots can be stored in the storage tube by the following steps:

1. Remove the television scan from the deflection plates.
2. Deflect the beam to the desired spot at which the writing operation is to take place.
3. Write a positive spot.
4. Repeat for each spot position.

Figure 10 shows the television display tube. A 20 by 20

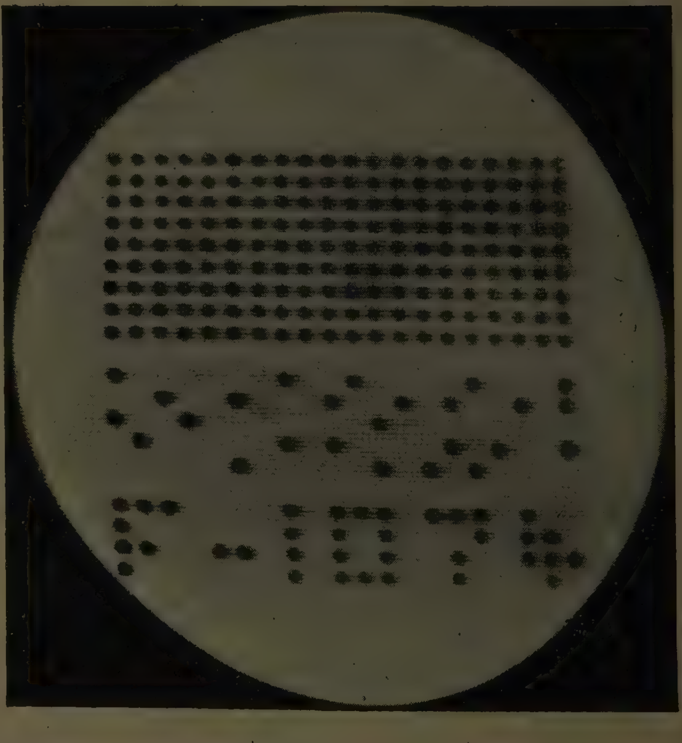

Figure 10. A television monitor-tube picture of the charge distribution on the storage surface of a storage tube

array of spots is shown with the top half all positive and the bottom half a random array of positive (ones) and negative (zeros) spots. This test is not typical of normal tube operation but gives a static visual display of the charge distribution on the storage-tube surface.

In addition to the television test set, a unit for dynamic operation of one to five storage tubes under conditions simulating computer operation is used to determine high-speed operating ranges. This dynamic tester cycles information in a storage tube by reading out the information from each spot in turn and writing the read-out information in the next.

A similar cycling technique is used also for testing tubes in the MIT digital computer itself. Figure 11 shows the installation of storage tubes and their associated circuitry in the storage row of the computer. The tubes are mounted inside mu-metal boxes with a second internal shield for protection from stray magnetic fields.

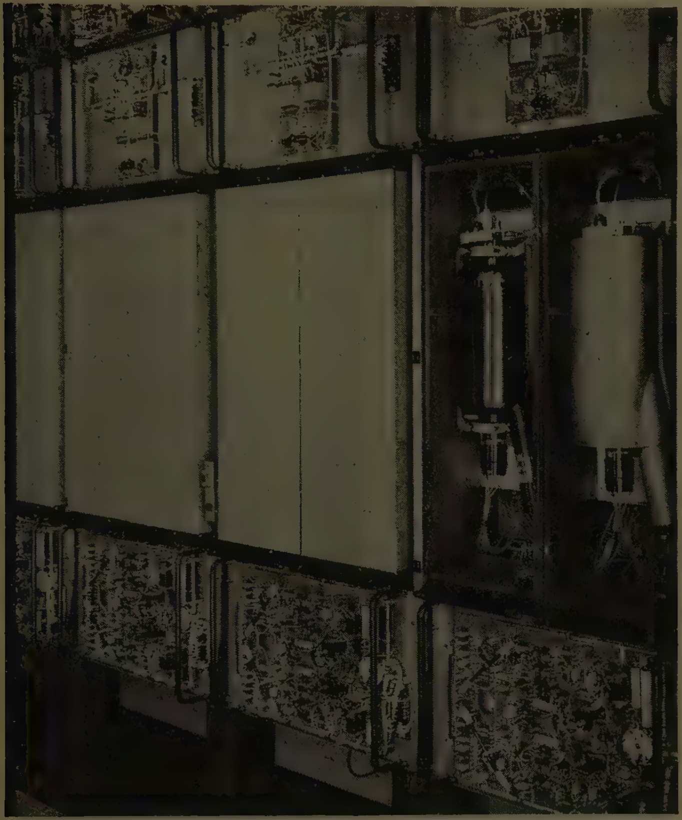

Figure 11. The electrostatic storage row in a computer. At the right, the covers have been removed from the mu-metal mount boxes to show the two storage tubes. The tube at the right is still enveloped in its internal mu-metal magnetic shield

Deflection circuits, under the control of the computer, position the write–read guns of all 16 tubes in parallel and the output signals are obtained simultaneously on separate lines. Access time has been increased in the initial computer installation in the interests of maximum reliability by providing rewriting and increased holding-gun time. As information on reliability is accumulated, some of these provisions may be found to be unnecessary and can be easily removed. A complete row of 16 storage tubes with their circuits has been installed and operated. An access time of 25 microseconds and storage density of 256 spots is adequate for initial computer requirements. Circuits and space for a total of 32 storage tubes, each operating at a density of 1,024 spots, have been provided.

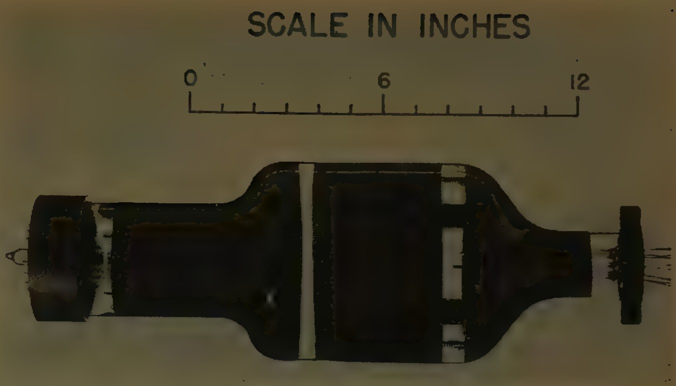

Figure 12. A new design of the MIT electrostatic storage tube. The writing–reading and holding guns are mounted at slight angles, pointing toward the center, in the one neck at the left. The storage assembly at the right has not been changed

APPLICATION IN COMMUNICATION

Besides the use of digital storage tubes in computers there may arise important applications of digital storage in communications systems. A limit to the number of channels for both wire and wireless information is being approached. More efficient use of present transmission facilities could be made by a bandwidth reduction or by reducing the required time of data transmission.

A generalized memory system consisting of two MIT electrostatic storage tubes has been set up under the direction of Professor J. B. Wiesner of the MIT Research Laboratory of Electronics to experiment with these communication applications. One storage tube, with its associated deflection system, can accept incoming binary-coded information at a random time and store this information until a complete array of information is available. Then the information in the storage tube can be read out rapidly and transmitted to a receiver while the second storage tube, with its associated circuits, takes over the role of receiving the incoming information. The system thus accepts information at a random time while giving an output in concentrated bursts.

During the development work on the MIT tube, the electron guns were mounted in separate necks to keep their operations carefully isolated. A more compact and simplified design has been made as indicated in Figure 12 where both guns are mounted in one neck. Future improvements are expected to result in decreasing access time toward six microseconds and increasing storage density for reliable operating storage to 1,024 binary digits.

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High-Speed Supervision of Process Variables

W. E. BELCHER, JR.

IMAGINE an instrument which scans rapidly through 50 primary elements in less than five seconds. It has no scale but has 50 bull's-eyes on the front of its case. Suddenly one of these bull's-eyes lights up and a howler sounds. A nearby recorder moves into action. The operator on duty notes the generator involved and presses a button to silence the howler, then leaves to inspect the stator of that generator. The bull's-eye remains lit and the recorder remains active. The temperature is dropping back toward a safe condition because the operator has increased the water flow to the hydrogen cooler. Next the light goes out and the recorder runs down scale and stops.

This instrument is sorely needed. It exists in the laboratory and practical versions are being developed. The need is present in the central station field and in the process industries. Already condensed instrument boards and graphic panels have been installed. The difference between central station and process industry applications is that in the process industries all the points requiring monitoring are process variables.

A review of the applications indicates that the problem of scanning may be broken down functionally into two main groups: monitoring and logging. A monitoring system, as shown in Figure 1, is one in which only the condition of the variable is indicated. Its primary function is identification by visible or audible signals of any variable which is beyond a given control range. With a monitoring system, logging of the variables is often required. This may require indicating instruments only, in which case the log is kept by the operator.

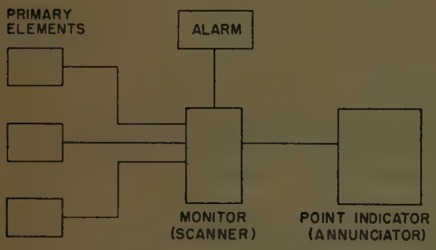

Figure 1. Basic monitoring system scans elements, gives alarm when one is out of control-range, and indicates bad element

A marked degree of flexibility must be built into scanning systems to satisfy as many applications as possible. Flexibility in the following respects is essential:

1. Number of points to be scanned.
2. Speed of scanning.
3. Means of selecting recorded or indicated points after the monitoring signal has been given.
4. Action which the monitor will automatically take after signal has been given.

It becomes obvious, as experience is gained in applications, that the greatest portion of the cost is not in the instrument mechanism, but in the installation of primary elements. A system for scanning 50 variables requires 50 primary elements or transducers and their lead wires. Therefore, the principal cost of the instrumentation would be determined by the characteristics of the location and type of measurement required.

In the system described, it is required that one or more set points be included and that the system have both high and low alarm features. For flexibility and ease of manufacture, it should be possible to set a given point to render alarm if the variable goes either high or low. The system then allows the utmost in flexibility. If it were desired to monitor 20 temperatures, five of which were to be both high and low alarms, and the other 15 simply high alarms, the complete system could be built on a 25-point basis.

The audible alarm is implicit in any monitoring system. Its operation can be the same for all systems. It is generally desired that when one variable is out of line, the howler may be cut off without affecting its operation in the event that other variables go out of line. It is also necessary for this alarm to reset itself when a variable returns to its normal value within the control range after the howler has been shut off.

All considerations relative to a monitoring system apply to a system with automatic logging. An automatic logging system is one in which recording or indication of the magnitude of the variable is initiated when the monitoring system so directs. Logging would thus take place on any out-of-line variable and would continue until it is returned within the proper limits.

Field surveys into industrial needs for instrumentation have brought to light a number of applications for this instrumentation. The most predominant among these is the checking of bearing temperatures in rotating machinery. These vary from aviation gas turbines through marine installations to central stations. The speed of scanning required runs from one point every two seconds to ten points per second.

Other applications are for flue-gas temperatures, atomic-pile temperatures, catalytic-cracking-unit temperatures, flows in petroleum processing units, and strain measurement. The speeds required in these cases are generally slower than one point per second. A far-sighted view of the situation, however, indicates that a great many other applications exist which are not known because of the limitations placed on the field surveys, and this is a new frame of reference for the instrument manufacturer.

Digest of paper 50-218, "High-Speed Supervision of Process Variables," recommended by the AIEE Committee on Power Generation and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–27, 1950. Not scheduled for publication in AIEE *Transactions*.

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Safety Testing of Electronic Equipment

O. G. WEDEKIND

Safety practices in design of electronic equipment are often overlooked for economic reasons. This article* treats the subject of electronic safety testing in general and emphasizes the point that designing originally from a safety viewpoint will introduce little additional cost and will, at the same time, enhance over-all quality.

INASMUCH AS the American industrial system is based on the fundamental concept of profit, it is understandable that some manufacturers will overlook the safety viewpoint in designing their products. All research is expensive and the product cost can be reduced by not pursuing the principles of safety engineering too thoroughly. Some companies dispense with engineering talent, others are not aware of fundamentals in safe design, and all are anxious to market their product at the earliest possible opportunity.

These thoughts are expressed without any idea of slighting the remarkable progress shown by free industry in adapting new techniques in the development of better equipment for the performance of everyday tasks. Consideration of the safety viewpoint should be a routine part of such development and if kept in mind can result in a far better product. Designing products to safety standards throughout the developmental stages inevitably will result in less expense than if the product must be revamped for safety reasons when development has been completed.

Electric equipment in general often is required to be installed in accordance with electrical codes enforced by local agencies. The National Electrical Code has been widely accepted as the basis for most local electrical installation ordinances. Certain sections of the National Electrical Code deal specifically with the installation of electronic equipment. Familiarity with these sections of the National Electrical Code often will enable the engineer to write into his product-design specifications many features which would facilitate compliance with installation requirements.

Since the National Electrical Code does not deal with the interior construction of equipment, the engineer should lay out a program which will assure the safe design of his finished product. It is the purpose of this article to outline briefly such a program specifically with respect to the testing of electronic equipment. The scope of this presentation is so general that it is possible only to deal with the broadest aspects of safety testing in the electronics field. The purpose of this article, then, is to serve as a general treatise on the subject of electronic safety testing and no attempt has been made to cover any phase in great detail.

TESTING METHODS

THE TECHNIQUES employed in testing electronic equipment are based on experience records of actual equipment. Therefore, the testing methods are set up to enable laboratory duplication of field performance. It is a fundamental safety concept that a hazard should not develop by reason of equipment failure in normal operation when installed as intended nor under any probable condition of abnormal use. As an example, a radio should be capable of normal operation for extended periods during which time there should be no evidence of a fire hazard. It should not be possible to develop a shock hazard by interchanging tube locations in any radio set even though this is not a normal condition of use.

Some of the more important and commonly recognized test procedures are outlined but it should be recognized that these serve only as guides. Additional tests will suggest themselves for various products once the basic thinking is understood.

Input Tests, Rating. To assure the use of electronic equipment on circuits of the proper potential, frequency, and current capability, the product should be marked with proper ratings and special installation or application instructions when necessary. These values can be determined by careful measurements on complete commercial samples under the conditions of actual use and with rated loads.

Heating Tests. Electronic equipment, in common with other electrical devices, can operate properly over a long period of time only if insulation is used at temperatures which are below values at which the useful life decreases rapidly. Therefore it is important that heating tests be made under conditions of normal installation, loading, and use. Temperatures should be measured on all insulation such as that on conductors and material used for supporting current-carrying parts, and should be compared with well-known and recognized limiting values for such materials. Temperatures are measured conveniently by means of thermocouples and potentiometer indicators, though the

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* Third in a series of four articles on safety. The first was "Perception of Electric Currents," C. F. Dalziel, T. H. Mansfield (*EE, Sep '50, pp 794–800*) and the second was "108 Are Missing," E. G. Hunt (*EE, Oct '50, pp 919–21*). Essentially full text of a conference paper presented at the Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950.

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resistance and thermometer methods also are employed.

Overload Tests. Overload or abnormal tests are commonly employed to obtain a quick evaluation of the performance of components using some overload factor or probable condition of abuse. A small number of operations, such as 50, usually suffices. Switch and relay contacts, motors and coils, and protective devices are tested in this manner. Failure of contact-making devices is indicated by excessive burning or pitting and sticking or arcing to grounded or opposite-polarity parts. Motors are tested under stalled-rotor or heavily loaded conditions. Thermal protection generally is indicated for motors remotely or automatically controlled, if stalled-rotor conditions result in winding temperatures in excess of 150 degrees centigrade.

Electrolytic capacitors are used frequently in circuits where direct current is obtained directly from an a-c supply circuit through a selenium rectifier. An abnormal test of the capacitor consists in applying the a-c line potential to the capacitor in series with a fuse. The capacitor should not explode violently nor ignite cotton placed around it. The test is representative of conditions following rectifier failure.

Endurance Tests. Endurance tests are employed to evaluate the mechanical and electrical stability of an assembly. Such tests are conducted at rated load and normal conditions of use. The number of operations depends on frequency of use and usually ranges between 1,000 and 100,000. All types of contact-making and -breaking devices are subjected to such tests to assure a reasonable electrical life. Mechanical features such as gears, solenoids, pulleys, levers, and so forth, are similarly tested and judged on the basis of test completion without failure and with reasonable wear if such failure would result in a hazard.

Solenoids frequently are intended for short-time duty only and overheat if continuously energized to such an extent that free movement of the plunger no longer is possible. In such cases, or in instances where free movement of the plunger is restricted by mechanical malfunction, the current flow is so high that coil burnout results in a very short time. The operation of solenoids often is so vigorous that ordinary lock washers will not suffice to hold fastening nuts and bolts in place. Endurance tests over a number of operations will show up such weaknesses.

Dielectric Strength Tests. Dielectric tests are performed to evaluate the adequacy of insulation and spacings. Such tests are based on some predetermined safety factor ranging from a value of 10 times for devices rated 50 volts or less to a value of 1.25 times circuit potentials for some television circuits operating above 15 kv. The test potential, obtained sometimes from auxiliary variable-potential transformers and sometimes from the equipment itself, is maintained for a period of a minute and should be gradually applied.

Insulation of the supply circuit from the enclosure and from exposed parts is tested at a potential of 900 alternating volts for most 120-volt appliances. For higher line potentials and for industrial equipment in general, a test potential which is twice the line potential plus 1,000 volts is employed.

For electronic circuits, which are usually isolated from the line by multiwinding transformers, test potentials are based on the circuit potential. A factor of three is employed for radio and sound equipment circuits and is obtained by applying up to three times the normal primary potential to the power-supply transformer at a corresponding higher frequency to eliminate possible core saturation. In television high-voltage circuits, the factor is reduced to 1.5 for potentials between 1,000 and 15,000 volts, with a minimum test value of 3,000 volts. Above 15,000 volts, the factor is reduced to 1.25, with a minimum test value of 22,500 volts. However, the factor of 1.25 is based not on operating potentials but on potentials which may exist due to circuit unloading such as occurs when heavy-drain tubes burn out or are removed.

X-ray circuits usually operate at potentials in excess of 50 kv and the test factor of 1.25 is considered appropriate. These potentials in secondary circuits are obtained by impressing 125 per cent of normal-rated potential on the power transformer primary.

Where electrodes are placed on the human body, insulation to the supply circuit is tested by application of 2,500 alternating volts between the supply terminals and body electrodes for a period of one minute.

Shock Hazard. Determination of hazard with respect to shock is based on values of current which have been determined from the findings of a number of observers. A maximum value of five milliamperes through an assumed body resistance of 1,500 ohms is considered acceptable. This value of current applies for direct currents and alternating currents up to a frequency of 60 cycles. Safe currents at higher frequencies and for other than sinusoidal wave forms have not been investigated in sufficient detail to enable the limiting values to be specified. The figure of 1,500 ohms for body resistance is replaced by a value of 500 ohms in cases where potentials exceed 125 volts, where moisture is a factor, or where exceptionally good contact is probable.

Where shock currents are derived from stored electric charges, the total amount of stored charge and the circuit time constant are limiting factors.

It frequently is more economical to provide an interlocked enclosure on high-potential equipment than to insulate interior serviceable components to assure freedom from shock hazard. Residual charges in such enclosures should be investigated on the basis of time required to establish bodily contact and ability of the circuit to deliver hazardous current values.

Special Tests. Although there are numerous special tests which could be applied to electronic equipment, it is not possible to mention more than a few of the most important.

Some equipment by its very nature brings about a hazardous condition in the event of failure to operate because of component failure. Such devices as fire-alarm controls and safety controls for gas- and oil-fired equipment are in this category. These devices should be so designed that a defective tube, open-circuited resistor or capacitor, short-circuited capacitor, or other defective component will be indicated if such a failure will result in a system nonoperative in its intended manner.

Diathermy and high-frequency induction and dielectric heating equipment can induce high currents in adjacent metal bodies, in some cases producing dangerously high temperatures. Diathermy equipment by its very nature often is employed in close proximity to bed springs and adequate precautions against hazardous currents in such metal must be taken by the technician operating the equipment. A warning label calling attention to the need for such caution by the technician is carried by the equipment.

Induced high-frequency potentials in structural members of industrial electronic equipment, though not in themselves hazardous, should be eliminated because the muscular reaction produced upon accidental contact may bring personnel in contact with moving machinery.

Overvoltage and undervoltage tests on solenoids, relays, and contactors should be made to determine acceptable operation of these components in the voltage range of intended operation of the equipment.

Construction. The over-all construction of the product should be subjected to careful consideration with an eye to durability and general suitability for its intended application. The physical strength and completeness of the enclosure must be judged on the basis of severity of service, protection of assembly from dirt and moisture, ventilation, corrosion protection, and mounting means. Facilities for supply connections and grounding, if required, should be in accordance with recognized standard practices. The stability of materials such as zinc-base die castings and rubber materials should be evaluated by standard tests. The enclosure of hazardous moving mechanisms should be sufficient to preclude possible accidental contact by personnel.

ELECTRONIC EQUIPMENT TESTS

THE FOREGOING discussion has been concerned with test procedures for electronic equipment in general. In the following examples specific tests which apply to various classes of electronic devices are outlined. The tests indicated are, of course, only those which would apply to the components usually employed; other special tests might be required if dictated by the nature of the assembly.

Radio and Sound Equipment. The testing of radio and sound equipment has become standardized to a considerable degree. The fire hazard in the ordinary transformer-powered radio has been reduced to a low value by complete enclosure of the transformer in its own metal enclosure. The transformerless set, which has become so popular in recent years, also has a commendable record in this respect and the use of complete metallic enclosures for the chassis is no longer considered a design requirement. The fuse action of the series heater string of the tubes in these sets serves to prevent the flow of large values of line current.

Shock hazard in transformer-type radio and sound equipment was never a serious problem, since most energized components were under the chassis. Transformerless sets, on the other hand, often are designed with a line-connected chassis, in which case a complete insulating outer enclosure and interlocking back usually are provided. Since tube replacement is considered a function often performed by the nontechnical user, it is important that the insertion of tubes even in the wrong socket shall not result in hazardous potentials appearing on shells of metal tubes, antenna terminals, and so forth.

Temperature, dielectric strength, and current-leakage tests are the major tests made on electronic equipment of this type to establish adequacy of the design from the viewpoint of fire and shock hazards.

Television. In addition to the usual tests given radio equipment, television equipment must be investigated for a number of possible hazards unique to the circuits and components employed.

1. Fire hazard can be measured only partially on the basis of a normal heating test. The high potentials produced, ranging from 6 to 30 kv or more, place severe demands on insulating materials. Insufficient spacings, inadequate insulation on wires, together with the extremely steep wave fronts and high transient potentials in some circuits, produce a combination of conditions conducive to arcing and possible insulation ignition. Such critical conditions can best be uncovered by applying elevated circuit potentials, preferably by driving or exciting the affected circuits. The choice of the multiplying factor is based on the normal circuit potential as previously mentioned.

Cotton- and rubber-insulated wires and flammable impregnants and waxes are inadvisable in high-voltage sections of television receivers, especially since noncombustible substitutes are readily available. An additional precaution is the use of an enclosure, such as a perforated cage, around the high-voltage generating section.

2. Shock hazards in television circuits usually are present in the high-voltage generating circuit as well as in line-connected chassis in some types of transformerless design. Elimination of shock hazard may take the form of a completely enclosed chassis with an interlocked back or, less frequently, by limiting the energy available at the picture-tube anode lead.

The capacity of coating on some types of picture tubes, together with the filter capacitor in the high-voltage circuit which is charged to the anode potential, forms a source of shock currents of dangerous magnitude.

Under some conditions it is possible for the picture-tube anode lead to become connected to earth ground. With such a condition, the insulation between the primary and core of the power transformer will invariably fail, placing line potential on the supposedly neutral chassis. Such a hazardous occurrence is readily eliminated by limiting the primary-to-chassis potential to a value of 1,000 volts or less by various expedients.

3. A hazard peculiar to television and related equipment exists by virtue of the large evacuated volume of the glass picture tube. Breakage of such tubes results in an

effect known as implosion. As contrasted to an explosion, particles of glass are forced inward in an implosion but are almost instantly thrown outward again in a forward direction. A clear safety glass or plastic window is commonly employed to guard against the hazard of tube breakage. Tubes may be broken by severe jarring of the cabinet or breakage may occur spontaneously.

Safety windows are tested by imploding picture tubes in place in the cabinet. Implosion is effected by striking a steel rod resting on the rim of the tube and projecting through a hole in the cabinet top. Acceptable performance is based on the size, weight, and distribution of particles thrown horizontally from the center of the picture-tube window.

The protective window also serves to guard the user in case the tube is broken by striking the window. The window is tested by delivering an impact of five foot-pounds upon its center. The window must be held securely in its frame and only small openings can be accepted.

4. Any tube, gas-filled or highly evacuated, is a possible source of X rays. The potentials employed on picture tubes can under some conditions produce X rays of dangerous quality and quantity. The X-ray radiation characteristics of all picture tubes must be checked to insure that the X-ray radiation level is within tolerable limits. At the present time, the dosage which is tolerable still is not definitely known. However, a value of 0.02 roentgen over an 8-hour period has been proposed. Special equipment and personnel skilled in its use are imperative in making reliable radiation measurements.

INDUSTRIAL AND COMMERCIAL ELECTRONIC DEVICES

EQUIPMENT employing electronic principles is being developed for many widely diversified applications. Heating and cooking of foods, sterilization of foods, heating and setting of glues, thermosetting plastics, welding of thermoplastics, casting of metals in vacuum, timing, measuring, weighing, and sorting are some typical functions performed electronically.

Equipment of this type generally is operated by nontechnical workers and must be designed to take into account the abuses suffered in the hands of such operators. Some commercial devices are designed for vending various products upon insertion of a coin. Other equipment is installed in unattended locations. All of these applications must be designed to operate without benefit of technical supervision and the testing program should be based on recognition of this fact.

The electronic circuits are tested in the manner outlined in the section on Testing Methods. The equipment is constructed in a manner comparable to that employed in industrial electrical products with heavier conductors, larger spacings, and better natural or forced-air cooling means than are found in radio equipment intended for domestic use.

Most industrial electronic equipments employ automatic controlling circuits and hence require protective devices to reduce hazards brought on by component failure. The operation and reliability of such protective devices should be determined by test. Motor protective devices (thermal and overcurrent), thermostats, limit control, and the like are tested under standards governing the performance of such devices and are beyond the scope of this presentation.

MEDICAL AND DENTAL EQUIPMENT

UNDER THIS classification are found such devices as X-ray machines, diathermy equipment, high-frequency surgery or cautery equipment, and muscle-stimulating equipment, all of which employ electronic circuits.

The testing of this equipment from a safety engineering viewpoint immediately poses a problem. Since the intended output of these devices is admittedly hazardous when indiscriminately applied to the human body, where does engineering stop in designing to eliminate hazards? X rays, shock-therapy currents, and diathermy radiations are admittedly valuable tools to the professional medical man. Therefore, a reasonable approach to the problem would be to assume that the dangers inherent in the nature of the output of these machines are properly under the control of professional medical personnel. Engineering tests then are concerned only with the proper performance of components without further consideration of the output. However, it must be recognized that the output circuits may still require testing with respect to hazards not associated with the basic output. For example, high-frequency surgical equipment would require a 2,500-alternating-volt test between the supply circuit and the scalpel, whereas the high-frequency cutting currents available from the scalpel would not be investigated from the standpoint of shock hazard.

Where equipment of this type is intended for nonprofessional use, for example, X-ray shoe fitters and electronic muscle-stimulating or reducing equipment, the nature of the output would necessarily be subject to examination. X-ray shoe fitters should be checked for emission of radiation from points other than the intended port or source. Reducing equipment of the electronic type for nonmedical use should be checked to determine that the output currents are not hazardous in character.

While it is often true that designing safety into a product results in added costs, it is less expensive to do so in the developmental stage than at any subsequent time. In the design of molds, jigs, and fixtures it usually costs no more to make such necessary changes. Very often a few hours of careful planning with an eye to safety will result in a far safer product at no cost increase. The public is becoming conscious of safety practices to an ever-increasing degree.

The manufacturer, intent on capturing future markets and building a reputation, can readily add to the sales appeal of his wares by adding safety engineering to the product design specifications. Since safety designing is merely the application of sound engineering for a specific purpose, it follows that over-all quality must be enhanced by such design.

By an orderly consideration of the points discussed, it is possible to assure reasonable life to a product, freedom from hazards to life and property, and frequently to accomplish these goals without appreciably increasing production costs.

Machine Synthesis

An Encounter With an Idea

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The method of designing a motor by machine synthesis rather than approaching it conventionally is being used more and more. With the more direct synthesis method much of the analysis of the design to determine its performance is eliminated; instead, desired performance characteristics are substituted in formulas to solve for the physical properties of the desired machine.

THE PROBLEM of designing a lamination and knowing how large to make a given motor is always a troublesome one, considered from a purely theoretical point of view. It is true that design texts make use of a D^2L equation, using the diameter and length to fix the volume, if not the proportions, of an armature of a polyphase induction motor. But so few data are given on the factors making up D^2L, that the method can hardly be considered reasonably exact.[1]

In industrial motor design the problem of selecting a size for a given motor rating is relatively less important than it is in theoretical design. National standards had fixed many frame sizes (and indirectly the lamination diameters). When special designs were to be made, competitive motors, customer demands, or the availability of existing laminations usually fix the diameters of the laminations.

Here is a partial solution to one bothersome question, that of size. But the procedure to be followed in designing a motor with the usual academic methods would apparently be as follows:

1. Select the proportions of the machine by more or less empirical methods.
2. Calculate the constants, and determine the performance.
3. Incorrect performance results in the need for readjustment by proportions, or, in some cases, complete redesign of the motor.

How serious this recalculation becomes depends somewhat upon the ingenuity of the designer and the difficulty of the original specifications.

In contrast to this traditional idea of design procedure, the early work of Dr. W. J. Branson makes it possible to follow a direct approach. For instance, in dealing with polyphase motors, he developed a method whereby it is possible to take a given stack of laminations, select the desired breakdown torque, and solve directly for the number of stator conductors needed to obtain this torque. The stator winding is thereby fixed, and by assuming a rotor end ring, the entire motor performance is fixed.

Such a procedure requires more ingenuity than it might seem from the mere recital of the fact. Examine the usual equation for the breakdown torque:

$$T_m = K(f) R_1,\ X,\ K_r,\ \text{rpm}$$

The transformation of this equation so that one can solve for windings in terms of torque still leaves the winding expressed in both resistance and leakage reactance, a clumsy form. But someone discovered earlier that when the contour of the magnetic circuit of a machine is fixed, it fixes the ratios of resistances to reactances, before the winding is actually known. This is a powerful tool, applicable to all types of induction and synchronous motors, and its discovery was an important contribution in machine design development.

This process is a direct approach, in contrast to the usual procedure previously outlined. When this approach was being used 15 years ago, it was applied to the determination of the main windings for single-phase and polyphase induction motors. The idea gradually grew that here was more than a useful tool for obtaining a few answers needed by the designer in his routine work. This involved the elements of an entirely new approach to design.

The steps given in the outline of the traditional design method involve analysis. That is, regardless of whether an experienced designer with many data at his command or a novice with nothing but a wild guess is about to make a design, he obtains a trial design and then analyzes it. All of the usual textbooks on machines deal largely with analysis. The machine and its constants are given, and one then proceeds by analysis to determine its performance. In such texts, the parameters are usually obtained by tests, with methods given. In conventional design texts, the method is shown for calculating the parameters from mechanical dimensions. This step is again followed by analysis, to determine if the design is acceptable.

In contrast, the new approach involved synthesis, the combination of several elements to make up a new and prescribed form. Dr. Branson, in setting up a direct method for determining a winding, developed the first steps in an entirely new field; electrical design by direct synthesis, applicable in a varying degree to all electric machines. Refer to the first method shown in Table I. This outlines the initial step in the synthesis of a polyphase

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induction motor, incomplete because it leaves the flux density undetermined and subject to a later adjustment of stacking. Method 2 outlines a method in which the stacking is not assumed, but the desired flux density is selected. Direct synthesis gives the number and size of conductors, as well as the stack, to obtain the required breakdown torque at the prescribed flux density.

Instead of assuming a rotor cage and analyzing the results obtained, the third step shown indicates that it is possible to take either starting current or torque as the critical item and solve directly for the end-ring area which is needed.

These methods are generally useful, but for certain motors, either double- or single-cage types, the starting current and torque may be more critical than the breakdown torque. The last two items in this table show that it is possible to initiate a design from these desired values using direct synthesis. This outline indicates the extent of design synthesis development in polyphase induction motors. In each case, some characteristics, although important, are not included in the critical items. These must be checked later, and to this extent, the ideal procedure for synthesis has not been achieved.

Such an ideal method would involve the use of all of the desired operating characteristics in a formula or series of formulas. The progressive solution of these would yield exact data on each of the items pertaining to the electric and magnetic circuits under the designer's control and would directly fix all machine dimensions and data. Theoretically, such a complete synthesis might be possible, but a cursory examination of the procedure indicates that the formulas would be too cumbersome.

Mention has been made of the fact that the Branson method of a direct solution of the main winding of a single-phase motor has been in use for many years. The procedure is outlined in Method 1 of Table II and indicates that the breakdown torque is used to fix the main winding. As shown in this table, a direct solution of the starting winding for the split-phase motor has been made possible. More recently, the work of Dr. S. S. L. Chang has greatly simplified the original complexity presented by the many variables of the capacitor-start motor. This synthesis (Table II) enables a direct solution to be made for the starting winding, usually in terms of desired starting torque.

The permanent split-capacitor motor has for years been a design anomaly. Few published data exist on the design; investigators in recent years have worked almost exclusively on methods of analysis. Again, some recent work by Dr. Chang has made possible a synthesis with the main winding fixed by the maximum torque and the auxiliary winding fixed by the starting torque.

An entirely new problem was presented by the application of synthesis to synchronous motors, both excited and unexcited types. Pioneer work by C. H. Crouse, J. H. Karr, and G. V. Meuller has resulted in a satisfactory direct solution for the statorc onductors and wire size needed to give a prescribed pull-out torque. For the d-c excited case, the field winding can be calculated directly as a supplementary step.

Table I. Polyphase Induction Motor Synthesis

Machine	Given	Criterion	Assume	Calculate	Solve For	Check	Reference
Polyphase squirrel cage. Method 1	Laminations	Breakdown torque	Stack, winding pitch, air-gap length	Parameter ratios: R_1/X, and so forth	Stator conductors, wire size	Flux density	1, 2
Method 2	Laminations, flux density	Breakdown torque	Winding pitch, air-gap length	Parameter ratios	Stator conductors, wire size, stack		1
To fix rotor winding. Stator fixed by Methods 1 or 2	Rotor bar size	Starting current or torque	End-ring proportions	Bar and ring ratios	End-ring area	Starting torque or current and full-load slip	1
Polyphase squirrel cage. Method 3, fixes stator and rotor windings	Laminations	Starting torque, starting current, full load slip	Stack, winding pitch, air-gap length, end-ring proportions	Parameter ratios in terms of impedance	End-ring area, stator conductors, wire size	Flux densities, breakdown torque	
Polyphase squirrel cage, double cage (Design C)	Lamination and complete double cage	Starting current (fixes impedances)	Stack, winding pitch, air-gap lengths	Parameters in terms of unit stator conductors	Stator conductors, wire size	Starting torque, breakdown torque, full-load slip	3

Table II. Single-Phase Induction Motor Synthesis

Machine	Given	Criterion	Assume	Calculate	Solve For	Check	Reference
Single-phase induction, main winding, and rotor. Method 1	Laminations	Breakdown torque	Stack, winding distribution, air-gap length, rotor cage	Parameter ratios: R_1/X, R_2/X	Stator conductors, wire size	Flux densities, full-load slip	4
Split-phase winding	Laminations as above, main winding	Starting torque or current	Winding distribution	Parameter ratios	Stator conductors, wire size	Starting current or torque	5
Capacitor-start winding	Laminations as above, main winding	Starting torque	Winding distribution, capacitor	Parameter ratios	Stator conductors, wire size	Starting current, voltage across capacitor	6
Permanent split capacitor, main winding	Laminations	Breakdown torque	Stack, winding distribution, air-gap length, rotor cage	Parameter ratios	Stator conductors, wire size	Flux density	7, 8
Capacitor (auxiliary) winding. Method 1	Laminations as above, main winding	Starting torque	Winding distribution, capacitor	Parameter ratios	Stator conductors, wire size	Starting current, no-load voltage across capacitor, full-load slip	7, 8, 6
Method 2	Laminations as above, main winding	Balanced operation at prescribed load	Winding distribution, capacitor	Parameter ratios	Stator conductors, wire size	Starting torque, starting current, no-load voltage across capacitor, full-load slip	7, 8, 6

Table III. Synchronous Motor Synthesis

Machine	Given	Criterion	Assume	Calculate	Solve For	Check
Synchronous motors, polyphase, d-c excited	Laminations, air gaps, pole enclosure	Pull-out torque	Stack, winding pitch, power factor and torque-angle	Ratios of reactances and resistances to direct axis reactance	Stator conductors, wire size, rotor wire size, rotor turns	Flux densities, rotor cage, pull-in torque, starting torque
Synchronous, polyphase, unexcited	Laminations, air gaps, pole enclosure	Pull-out torque	Stack, winding pitch	Like above	Stator conductors, wire size	Flux densities, rotor cage, pull-in torque, starting torque
Synchronous, single-phase	Laminations, air gaps, pole enclosure, rotor cage	Pull-out torque	Stack, winding pitch	Like above	Stator conductors, wire size	Flux densities, pull-in torque, and starting winding

Table IV. Direct-Current and Universal Motor Synthesis

Machine	Given	Criterion	Assume	Calculate	Solve For	Check	Reference
D-c shunt, series, and compound	Laminations, magnetization curve, commutator, rotational losses	Output, speed	Stack, ratio of field to armature ampere turns, brush lead, brush drop	Volts per turn	Field and armature turns and wire size	Performance, commutation, no-load speed (or regulation)	9
A-c series	Lamination, magnetization curve, commutator, rotational losses	Output, speed	Stack, ratio of field to armature ampere turns, brush lead, brush drop	Speed and transformer voltages per turn	Field and armature turns and wire size	Performance, commutation	10

Progress and method on these motors are outlined in Table III. They depended upon the little-known fact that leakage reactance and the resistance, as functions of the direct-axis reactance, are fixed as soon as the laminations are selected. No detailed exposition of these methods has appeared in print.

Nearly all of the published methods on d-c design make use of empirical data for establishing dimensions and windings and follow this by analysis of the results. Actually, design synthesis on these motors and generators has been achieved with laminations given. Unlike the induction motors, where speed can be more or less taken for granted by fixing the number of poles, both speed and horsepower output become the criterion for a direct solution of the required windings. This method has been used for about eight years with satisfactory results.

Universal motors or motor parts have depended almost entirely upon empirical design based largely upon trial-and-error methods. Few data can be found in print concerning their analyses, and practically nothing covering their design. In order to develop a method of design synthesis, it was found necessary to predict accurately the rotational losses. No expression for net output was useful without considering these large losses. Work by J. H. Karr and S. S. L. Chang has resulted in a calculation method which has become a part of a design synthesis for universal motors. The steps are shown in Table IV.

All of this has represented a new field of investigation, and this article gives a partial picture of the useful progress which has been made. Of course, it is electrical design which has spurred the work on and made it practicable, and yet, the relationships revealed by synthesis might prove of value in attempting to teach machinery courses in general. Viewed from this background, the predilection of the academic world with analysis seems narrow. In practically all courses in machinery or in attendant laboratory work, given machines are analyzed. How did they come into being? Are our faculty members forced to tell each inquiring student that the doctor brings them in his black bag?

It is true that synthesis is related to electrical design and that electrical design is academically unpopular, but those colleges still teaching such courses might find that design, built around the approach of synthesis, could be revitalized. This would be aided by the important way in which synthesis differs from the traditional trial-and-error procedure.

Design has been defined as both an art and a science. It is an art because of the uncertain factors, the decisions involving judgment or experience. Synthesis involves the very elements of the design procedure which are exact, which are based on known physical laws, rather than judgment. Only in so far as synthesis has not yet developed for certain parts of a design procedure is experienced judgment still vital in design. The progress already made indicates that a design course based on synthesis would result in a more straightforward procedure with fewer decisions between one uncertain factor or another. It is this latter condition which is so confusing to the novice in trying to learn design in its academic presentation.

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Analogue Methods for Turbojet Thrust Instrumentation

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MEASUREMENT of the thrust of a turbojet engine during flight presents a typical application of analogue techniques for automatic measurement, computation, and actuation. Effective operation of military aircraft requires instrumentation which includes an indication of engine performance. With the introduction of turbojet aircraft came the demand for instrumentation which involves measuring the engine's thrust. However, the components of thrust are not directly measurable during flight. Therefore, thrust must be computed according to the thermodynamic parameters of engine operation.

The net thrust of a turbojet engine is the difference between the gross thrust of the exhaust gases and the ram-drag occurring at the air intake. It is desired to record and/or indicate the gross thrust continuously during flight evaluation tests rather than collect parameter data during the flight and calculate the gross thrust characteristics after the flight is completed. Gross thrust F_g can be expressed as a function of total pressure P_t and static pressure P_s at the exhaust nozzle and the ambient pressure P_a. For an effective exhaust area A and a ratio of specific heats γ for the exhaust gases, it can be shown that the gross thrust is

$$F_g=\underbrace{AP_s\left[\frac{2\gamma}{\gamma-1}\left(\frac{P_t}{P_s}\right)^{\frac{\gamma-1}{\gamma}}-1\right]}_{\text{momentum thrust term}}+\underbrace{A(P_s-P_a)}_{\text{pressure thrust term}}$$

This equation can be simplified for application of analogue techniques without sacrificing accuracy by expanding the bracketed portion of the momentum thrust term into an infinite power series of P_t/P_s assuming γ constant. An empirical representation using the first three terms of such a series gives

$$F_g=A[K_1P_s+K_2P_t+K_3P_t^2/P_s+K_4(P_s-P_a)]$$

With proper choice of constants K_1, K_2, and K_3, the latter equation is accurate to ±0.3 per cent. K_4 equals unity.

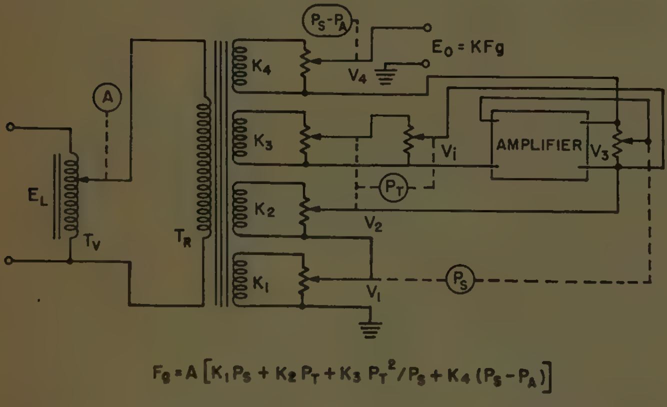

Figure 1. Schematic diagram of a gross thrust computer

An automatic solution of the simplified equation can be obtained by converting exhaust-pressure measurements to electric signals by suitable transducers. The transducers used in the prototype model, called the Jet Thrust Computer, are linear low-torque potentiometers, which are driven by mechanical linkages from either absolute or differential types of pressure-sensing elements. Pressure measurements are obtained from a rake in the exhaust nozzle. The voltages from the pressure-actuated potentiometers are combined in the computer so that the output of the computer is proportional to the gross thrust.

A schematic diagram of the Jet Thrust Computer is shown in Figure 1. The alternating voltages applied to the potentiometers are the secondary voltages of a special ratio transformer T_R designed to supply the equivalent constants K_1, K_2, K_3, and K_4. The displacements of the wiper arms on the potentiometers are proportional to the applied pressures. The analogue of the first term of the equation is produced as follows: The primary voltage of the ratio transformer is obtained from an alternator operating at the line voltage of the aircraft through an autotransformer T_V. This autotransformer is adjusted to supply a voltage proportional to the exhaust area A. This voltage is multiplied by the turns ratio K_1 of the ratio transformer. Thus $V_1=kAK_1P_s$, where k is the factor of proportionality between the absolute static pressure and displacement.

Likewise, the second term is proportional to V_2, where $V_2=kAK_2P_t$. Since the resistance of the second potentiometer in series is very much larger than the first, $V_t=k^2AK_3P_t^2$. This voltage is divided by the static pressure with the negative feedback amplifier to produce the analogue of the third term. That is, $V_3=\frac{-V_tG}{1+kP_sG}$, where G is the gain of the amplifier. The gain is sufficiently large so that $V_3=\frac{-V_tG}{kP_sG}=\frac{kAK_3P_t^2}{P_s}$.

The analogue of the fourth term is produced using the same technique as for the first term except that the displacement, on the K_4 potentiometer, is proportional to (P_s-P_a) which is obtained from a differential-type pressure transducer. It is noted that these four voltages (V_1, V_2, V_3, and V_4) are connected in series so that the output voltage V_o is proportional to the required gross thrust. V_o can be indicated by a voltmeter calibrated in units of gross thrust.

Digest of paper **50-212**, "Analogue Techniques for Turbojet Thrust Instrumentation," recommended by the AIEE Committees on Air Transportation and Computing Devices and approved by the AIEE Technical Program Committee for presentation at the AIEE Middle Eastern District Meeting, Baltimore, Md., October 3–5, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Voltage Changes Produced by Single-Phase Loads

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THE PROBLEM of determining the voltage change produced by a single-phase load has become one of considerable importance to the utility engineer. One of the principal reasons for this situation is the application of single-phase resistance welding to many new processes. The usual type of single-phase resistance welder requires for its operation large intermittent values of kilovolt-amperes at a low power factor. This type of load will, of course, produce voltage fluctuations on the power system adjacent to the welder. If these variations are severe enough, they may cause objectionable lighting flicker to other customers served from the same portion of the power system. The usual range of permissible voltage variation is from 0.5 to 1.5 volts on a 120-volt base. The actual value is dependent upon the type of welder load—whether cyclic or noncyclic—and if cyclic, upon the frequency of the load application.

Since such variations are objectionable, it is necessary that the power company engineer be able to determine accurately what the variation in voltage will be in order to provide adequate service at the lowest cost. In general, these problems have been handled satisfactorily with considerable ingenuity in devising schemes to keep the cost of service reasonable. However, in some cases the voltage drop measured after a welder was installed was appreciably lower than had been calculated. It was reasoned by many power company engineers that this discrepancy was caused by motor loads which were adjacent to the welder and which had been neglected in calculating the voltage drop. A study of the effect of such 3-phase motor loads has been made in co-operation with the Utilities Research Commission of Chicago, Ill.

The solution of this problem was accomplished by the use of symmetrical components in a manner similar to that used for unbalanced fault calculations. This was done by considering the single-phase load as a line-to-line fault having an impedance equal to that of the single-phase load. A typical system for supplying a large single-phase load such as a welder is shown in Figure 1. Equations have been developed which give the voltage changes produced at both *P* and *F* by the single-phase load. The change in voltage that is calculated by this method includes the effect of the motor loads at both *P* and *F*. The method of analysis used for the particular circuit shown in the figure can be extended to other types of circuit configurations that might be encountered.

This method of solution has been checked by both laboratory and field tests. Field tests were conducted at two plants having single-phase welder installations, with one plant supplied at four kv and the other at 34.5 kv. These tests were performed to determine how measured voltage drops would compare with those calculated by the method described, using field data. The results checked well within the accuracy normally expected in field tests. In the laboratory tests the measured data were in close agreement with the voltage changes that had been calculated and which included the effect of the adjacent motor loads.

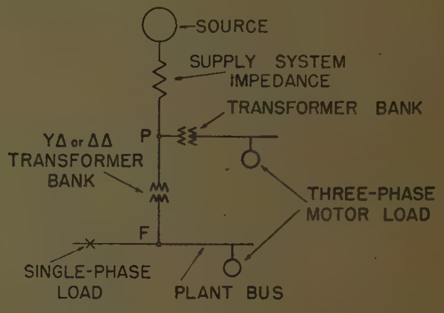

Figure 1. A typical system for supplying a single-phase welder load

The results of this study show the following:

1. Three-phase motors adjacent to a single-phase load reduce the voltage on the phase or phases which have the largest drop in voltage.
2. The effect of the motor loads can be calculated by the method of analysis that has been indicated previously in this digest.
3. This effect can be appreciable and should be included in an accurate analysis of the voltage change caused by a single-phase load. Calculations have been made for several actual single-phase welder installations. Calculations for these installations show that reductions in the voltage drop in the order of 25 per cent may reasonably be expected.
4. The amount of load on either a synchronous or induction motor has little effect on the voltage change caused by a single-phase load.
5. The excitation of a synchronous motor has little effect on the voltage change which is caused by a single-phase load.
6. In practical cases it is found that the exact character of the motor load adjacent to the single-phase load usually cannot be determined. It also is found that the motor loads are usually induction motors. Because of this and the preceding statement concerning the effect of the load on a motor, the voltage drop caused by a single-phase load usually can be determined with sufficient accuracy by using the average full-load and blocked-rotor impedances for the positive- and negative-sequence motor impedances, respectively.

Digest of paper **50-236**, "Effect of 3-Phase Motor Loads on Voltage Changes Produced by Single-Phase Loads," recommended by the AIEE Committees on Electric Welding and Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–7, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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High-Voltage Ignitron Rectifiers

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THE DEVELOPMENT of new types of sealed ignitron tubes has made possible rectifier equipment which is capable of delivering high power at moderately high direct voltages. The lack of moving parts, long tube life, and practically unlimited emission of the pool cathode are advantages which provide a high degree of reliability. These factors bring to the high-voltage field the same high efficiency and high grade of performance which is characteristic of the low-voltage industrial rectifier equipments. A 2,500-kw unit and a 7,500-kw unit represent typical designs of 17,000-volt rectifiers. The former employs a 50-ampere sealed ignitron tube and the latter employs a 150-ampere tube. The 6-phase double-way power circuit is employed in both units because it provides better utilization of transformer capacity than other rectifier circuits. The double-way connection requires only three secondary windings on the rectifier transformer and only three high-voltage connections between the transformer and the tubes, thus requiring less insulating material on the a-c side than other power circuits.

The 50-ampere sealed ignitron tube is 22 inches high and weighs approximately 25 pounds. The 150-ampere sealed ignitron tube is 42 inches high and weighs approximately 100 pounds. The internal structure of the tubes is similar to that of other types of sealed ignitrons except for the addition of the gradient grid. Current flow is initiated each cycle by the application of control grid voltage after the ignitor has established a cathode spot. Each ignitron carries a momentary surge current rating approximately 30 times its continuous rated value, which provides sufficient fault current capacity for most applications.

The 2,500-kw unit is assembled in five cubicles: three tube cubicles, a d-c cubicle, and a control cubicle. The 7,500-kw unit is assembled in four cubicles: three tube cubicles, and a control cubicle. The symmetry of the power circuit allows several possible circuit arrangements on the d-c side, according to the particular installation requirements.

The double-way circuit, shown in Figure 1, provides a natural grouping of circuit components and is the basis for the arrangement of the tube cubicles. The tube assemblies are mounted side by side in the 7,500-kw unit, one above the other in the 2,500-kw unit. All water piping and insulating transformers are mounted on the floor of the cubicles. The sealed ignitrons are insulated by neoprene hoses with high-resistivity distilled water as the recirculated coolant. Anode heaters maintain the proper anode seal temperature to prevent condensation of mercury near the tube anode.

The phase-shifting network is capable of adjusting the excitation voltages over a range of 150 degrees, thus providing smooth control of the direct voltage from zero to maximum. The excitation circuits are arranged to protect the tubes in the event of an ignitor misfire and to provide high speed arc suppression of the ignitrons for interrupting the d-c load current. Key operated door interlocks are provided in a sequenced arrangement on all high-voltage compartments for safety purposes. A relay control system is incorporated in the excitation system to insure the proper starting and stopping sequence of the rectifier auxiliaries.

The operating features of this rectifier equipment make it suitable for many applications in the moderate voltage field. Some of these are as power supplies for radio transmitters, particle accelerators, high-voltage testing, or power-system frequency changing.

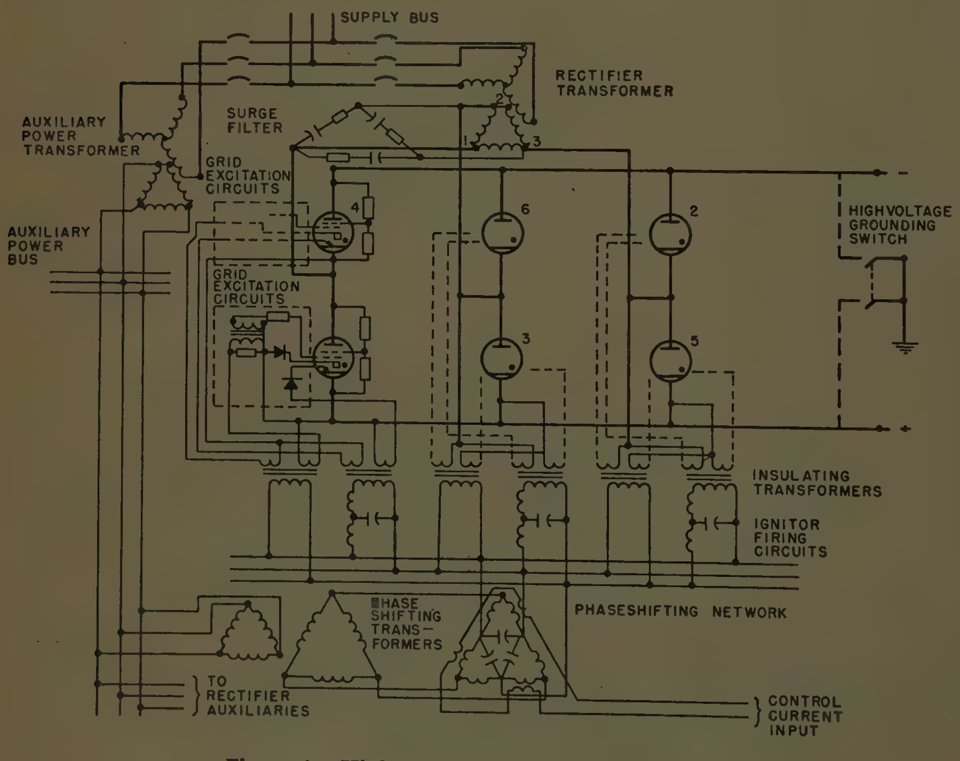

Figure 1. High-voltage rectifier circuit diagram

Digest of paper 50-146, "High-Voltage Ignitron Rectifiers," recommended by the AIEE Committee on Electronic Power Converters and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Marking of Varmeters

AN AIEE COMMITTEE REPORT

A survey of operating practices with respect to the marking of varmeters has been made under the sponsorship of the Instruments and Measurements Committee. Although the results show a wide divergence of practice, the "In" and "Out" markings are most commonly used, with "In" at the left of the scale.

AN INVESTIGATION to determine the practice of operating companies regarding the marking of varmeters has been completed by a subcommittee of the Instruments and Measurements Committee appointed to study this subject.

A questionnaire was sent to 106 operating companies in order to obtain the desired data on current practice. The questionnaire was in the form of a diagram of an imaginary system showing probable varmeter locations and assumed direction of quadergy* flow, with spaces provided for the indication of the scale marking of each instrument and the direction of deflection under the assumed conditions. (See diagram in Figure 1.)

Following is a summary of the replies received from the 48 companies replying, which constitute about 45 per cent of the 106 questionnaires sent.

TYPE OF MARKING

TYPES OF SCALE MARKINGS are listed in Table I together with the number of companies reporting the use of each type in one or more locations.

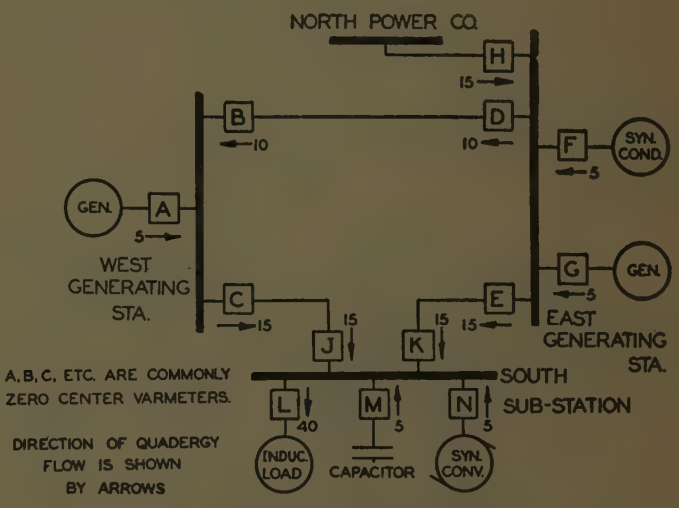
Attention is called to the fact that although reports were received from only 48 companies, the summation of the number of companies using each type of marking is 67. This indicates that a number of companies use more than one type of marking.

"In" and "Out" markings are the most common and are used by about 52 per cent of the companies reporting. This marking is used exclusively by 16 companies (33 per cent). Three of the ten companies reporting the use of "Lag" and "Lead" indicate that the instruments are power factor meters rather than varmeters.

Twenty-five of the companies use left-hand zero instruments at certain locations instead of the center or off-center zero type. Table II is a list of the left-hand zero scales reported and the number of companies using each marking. The use of left-hand zero instruments is distributed as shown in Table III.

Table I. Center and Off-Center Zero Instruments

Category	Scale Marking	Companies Using		Per Cent
1	In-0-Out	28		
	Out-0-In	7	35	52
2	Lead-0-Lag	6		
	Lag-0-Lead	4	10	15
3	To-0-From	2		
	From-0-To	3	5	7 1/2
4	Minus-0-Plus	3		
	Plus-0-Minus	1	4	6
5	Buck-0-Boost (Synchronous Condenser)	1		
	Boost-0-Buck (Generator and Synchronous Condenser)	1	2	3
6	Received-0-Delivered		2	3
7	Under excited-0-Over excited (Generator, Synchronous Condenser, Synchronous Converter)		1	1 1/2
8	Value-0-Value		5	7 1/2
9	To specific point-0-to specific point		3	4 1/2
			67	100



A, B, C, ETC. ARE COMMONLY ZERO CENTER VARMETERS.

DIRECTION OF QUADERGY FLOW IS SHOWN BY ARROWS

Reference—Bus in All Cases

West Station Meter	In	Out	East Station Meter	In	Out	South Substation Meter	In	Out
A	5	—	D	—	10	J	15	—
B	10	—	E	—	15	K	15	—
C	—	15	F	5	—	L	—	40
	15	15	G	5	—	M	5	—
			H	15	—	N	5	—
				25	25		40	40

Reference—Generator and Bus

West Station Meter	In	Out	East Station Meter	In	Out	South Substation Meter	In	Out
A	—	5	D	—	10	J	15	—
B	10	—	E	—	15	K	15	—
C	—	15	F	5	—	L	—	40
			G	—	5	M	5	—
			H	15	—	N	5	—

Figure 1. Imaginary system

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* *Quadergy.* In describing the operation of an a-c system with reactive loads, it has been found convenient to assume the existence of this quantity, which is analogous to energy, which is inherently positive, and which is assumed to flow out of a properly excited source and into an inductive load. A proposed definition of quadergy is: "The quadergy which has been supplied by a source to a load during a time interval is the integral with respect to time of the reactive power at the points of entry of the load taken over the time interval. The value of quadergy is given in varhours when the reactive power is in vars and the time is in hours."

This report was prepared by a subcommittee of the AIEE Instruments and Measurements Committee consisting of A. B. Craig, *Chairman*; A. L. Brownlee, A. L. Carvill, W. G. Knickerbocker, A. E. Knowlton, F. A. Redding, F. B. Silsbee, and H. B. Smith.

Table II. Left-Hand Zero Instruments

Scale	Number of Companies
0-in	9
0-out	10
0-lag	1
0-to	3
0-from	4
0-plus	1
0-delivered	1
0-value only	4
0-to specific point	3
	36

Table III. Distribution of Left-Hand Zero Instruments

Location	Number of Companies
Generator	3
Inductive load	22
Capacitor	21
Synchronous converter	1
Synchronous condenser	2

REFERENCE POINT

Table IV shows how the companies divided with respect to the point used as a reference for the markings of the varmeters at various locations.

Table IV. Reference Point for Marking Varmeters

	Number of Companies	
	Reference Point	
Location	Machine or Load	Station Bus
Generator	29	14
Inductive load	8	23
Capacitor	11	17
Synchronous converter	15	22
Synchronous condenser	18	20
Tie line	3 (other station)	39
Line to substation		
Station meter	4	37
Substation meter	6	35

Nine of the reporting companies use the station bus as a reference in all cases. The majority (about 65 per cent), however, use the generator as a reference point for the generator varmeters and the bus as a reference for those in the lines.

DIRECTION OF DEFLECTION

Table V shows the number of companies reporting right- or left-hand deflection of center or off-center zero instruments in each of the positions listed.

Table V. Direction of Deflection

		Number of Companies	
		Deflection	
Location	Direction of Quadergy Flow	Left	Right
Generator	From generator	10	33
Inductive load	To load	6	10
Capacitor	From capacitor	8	2
Synchronous converter	From converter	15	21
Synchronous condenser	From condenser	14	27
Tie line	To station bus	35	9
Line out to substation	From station bus	7	35
Line into substation	In to substation	30	11
Incoming line	To station bus	2	39

All companies reporting do not use varmeters at every point shown in the questionnaire. The number of companies reporting no instruments at various points is as follows:

Inductive load	6
Capacitor	12
Synchronous converter	10
Synchronous condenser	4
Lines	2

Several companies, although reporting that varmeters are not used at some of the points shown, indicated the probable scale marking if they should use varmeters at these points.

DISCUSSION

In general, the replies show a wide divergence of practices which apparently depend largely upon individual preferences. The points on which the greatest number of companies are in agreement are, the use of In-0-Out markings ("In" on the left), the use of the station bus as a reference point for line varmeter markings, and the use of the generator as a reference point for the generator varmeter.

However, another practice followed by nine of the reporting companies specifies the use of the bus as a reference point in all cases. This method presents the advantage that the sum of the "In" varmeter readings on a particular bus should always equal the sum of the "Out" readings. (See log sheet in Figure 1.)

It is interesting to note that 67 per cent of the companies replying, in their load dispatching evidently make use of the concept that there is a quantity which flows from one part of the system to another, and in so doing goes "In" and "Out," "To" or "From," and is "Received" and "Delivered." These are the companies listed in categories 1, 3, 6, and 9 of Table I. This fact seems to the committee to justify the introduction by the AIEE Committee on Instruments and Measurements into engineering parlance of the new word "quadergy" to designate this quantity. Reactive power is the measure of the rate of flow of the quantity, but strictly speaking, reactive power does not flow but merely is maintained at the load terminals by the action of the power system.

The results of the survey indicate that the establishment of a standard for the marking of varmeters is desirable. Therefore, in conformance with the present practice of the greatest number of reporting companies, the committee recommends that the "In" and "Out" marking be adopted as standard, and in center zero or off-center zero instruments, that "In" be on the left.

The committee calls attention to the advantages of uniformity and of a quantitative check on log sheets, which can be obtained by the use of the bus as a standard reference point.

Any comments on this report will be welcome and should be forwarded to the Chairman of the Subcommittee for Marking of Varmeters and Related Instruments, A. B. Craig, Boston Edison Company, 39 Boylston Street, Boston 12, Mass.

Fault Location by Pulse Time Modulation

R. W. HUGHES NELSON WEINTRAUB

This article describes the idea of locating faults on a power line, automatically and instantaneously, by means of fault-generated surges, and the use of a pulse-time-modulation radio system as the communication link necessary to the fault location operation.

THE PROBLEM of locating faults on a power line has long plagued the power industry. It is particularly troublesome since approximately 90 per cent of all faults are not sustained and hence the location of the fault must be determined on an instantaneous basis. In order to keep a record of the time and location of all faults, a method based on the measurement of the time required for a wave to travel from the fault to a substation appears most practical.

The system proposed by R. F. Stevens and T. W. Stringfield* is based on this method and is explained in detail as follows:

1. A fault occurs somewhere between *A* and *B*, the two ends of the power line. This starts a steep wave front surge along the line in both directions at the rate of 0.186 mile per microsecond.

2. Assuming *A* to be the recording station, the arrival of the surge there causes an electronic counter to be triggered.

3. At station *B* the surge is detected, converted to a convenient size pulse, and transmitted from *B* to *A* via a broad-band radio link.

4. The arrival of this second surge pulse stops the electronic counter, and from the elapsed time, the location of the fault may be calculated.

5. By the addition of some simple supplementary equipment, the counter can be arranged to read distance to the fault directly, and this permits the recording of the information for a permanent record in a fashion similar to the following:

"May 10, 1949 03:45:11 168.6 MI"

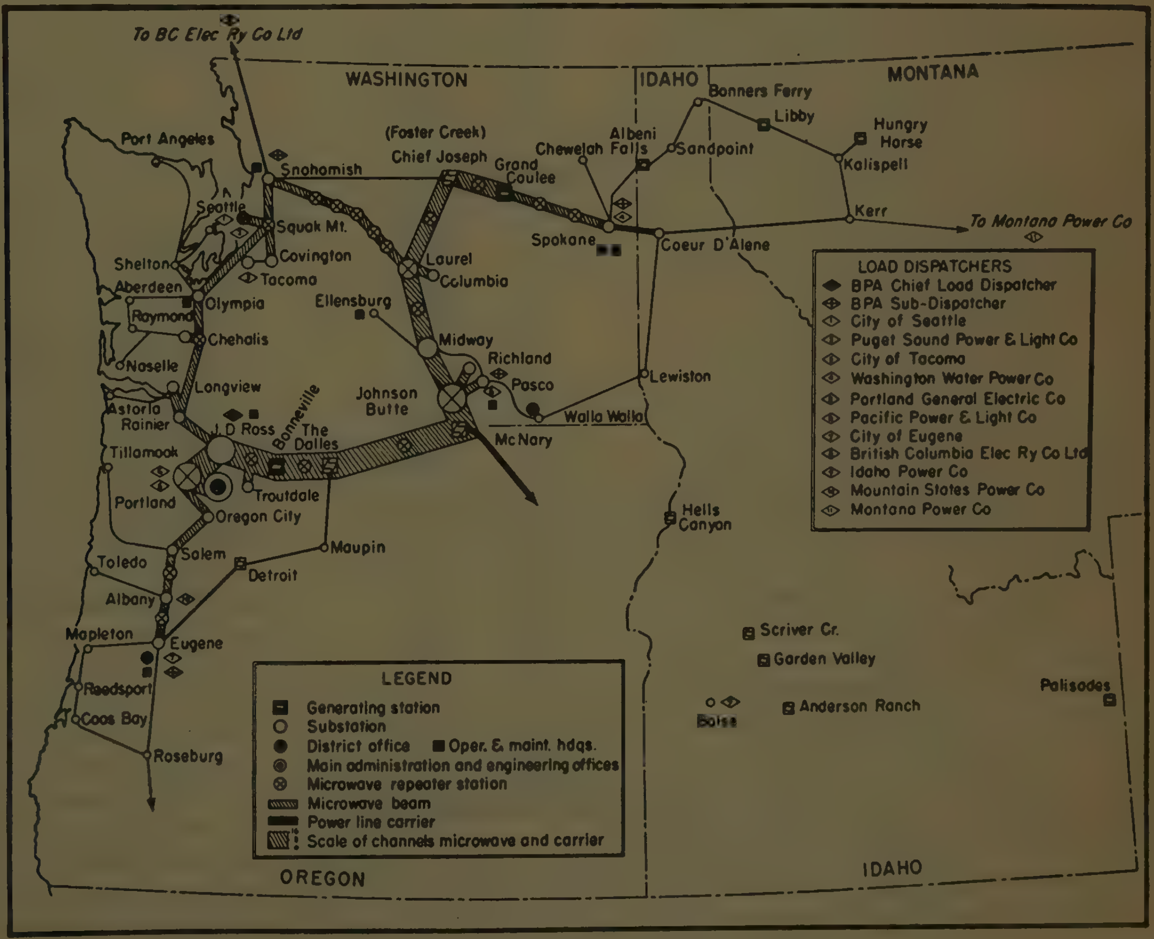


Figure 1. Proposed Bonneville Power Administration communication system as of 1954

Reprinted from Electrical World, "Microwaves Supplement Present Channels," R. F. Stevens, January 1, 1949

R. W. Hughes and Nelson Weintraub are both with the Federal Telecommunication Laboratories, Inc., Nutley, N. J.

* See "Transmission Line Fault Locator Using Fault Generated Surges," R. F. Stevens, T. W. Stringfield. AIEE *Transactions*, volume 67, part 2, 1948, pages 1168–78.

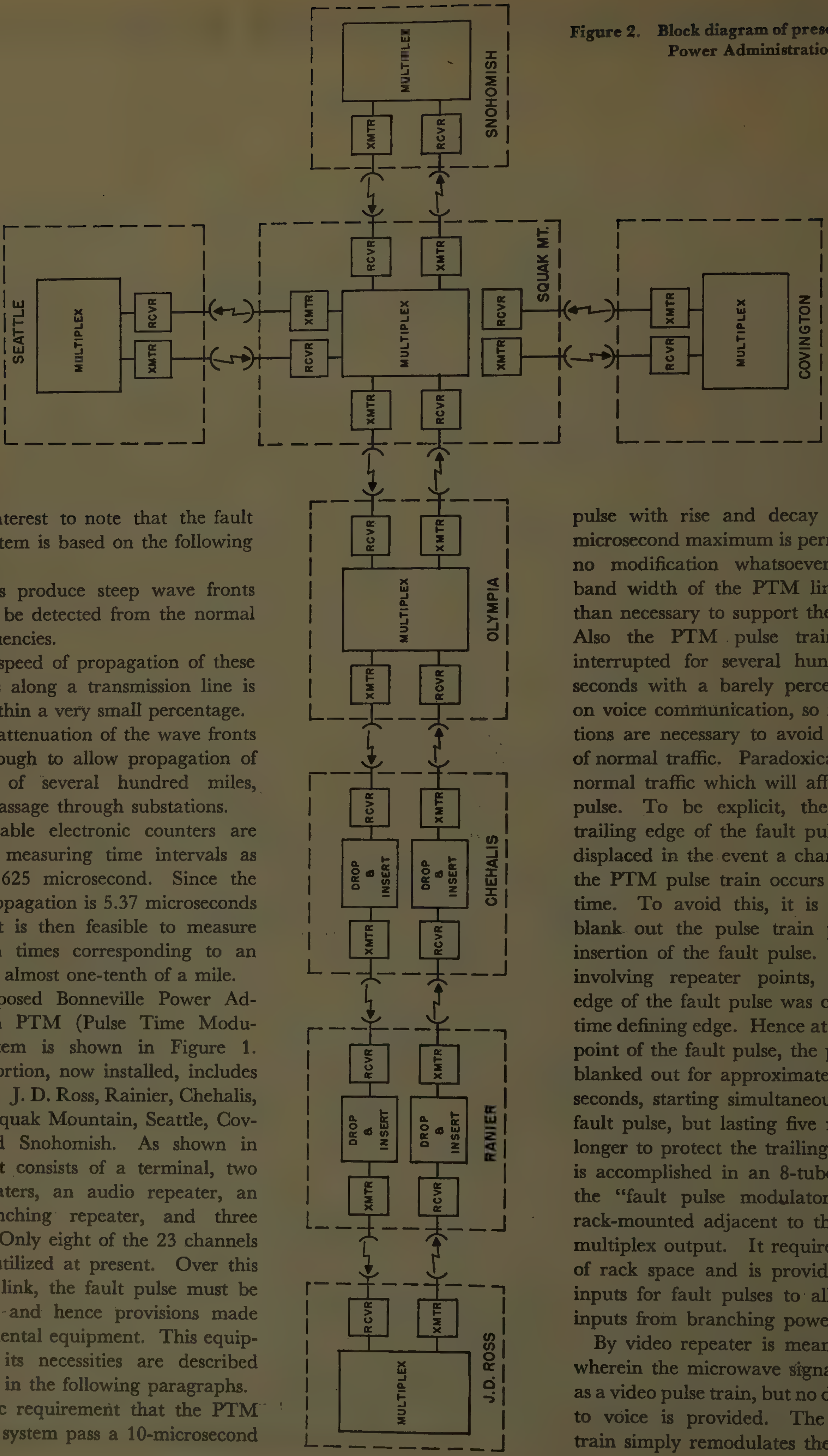


Figure 2. Block diagram of present Bonneville Power Administration

It is of interest to note that the fault locating system is based on the following facts:

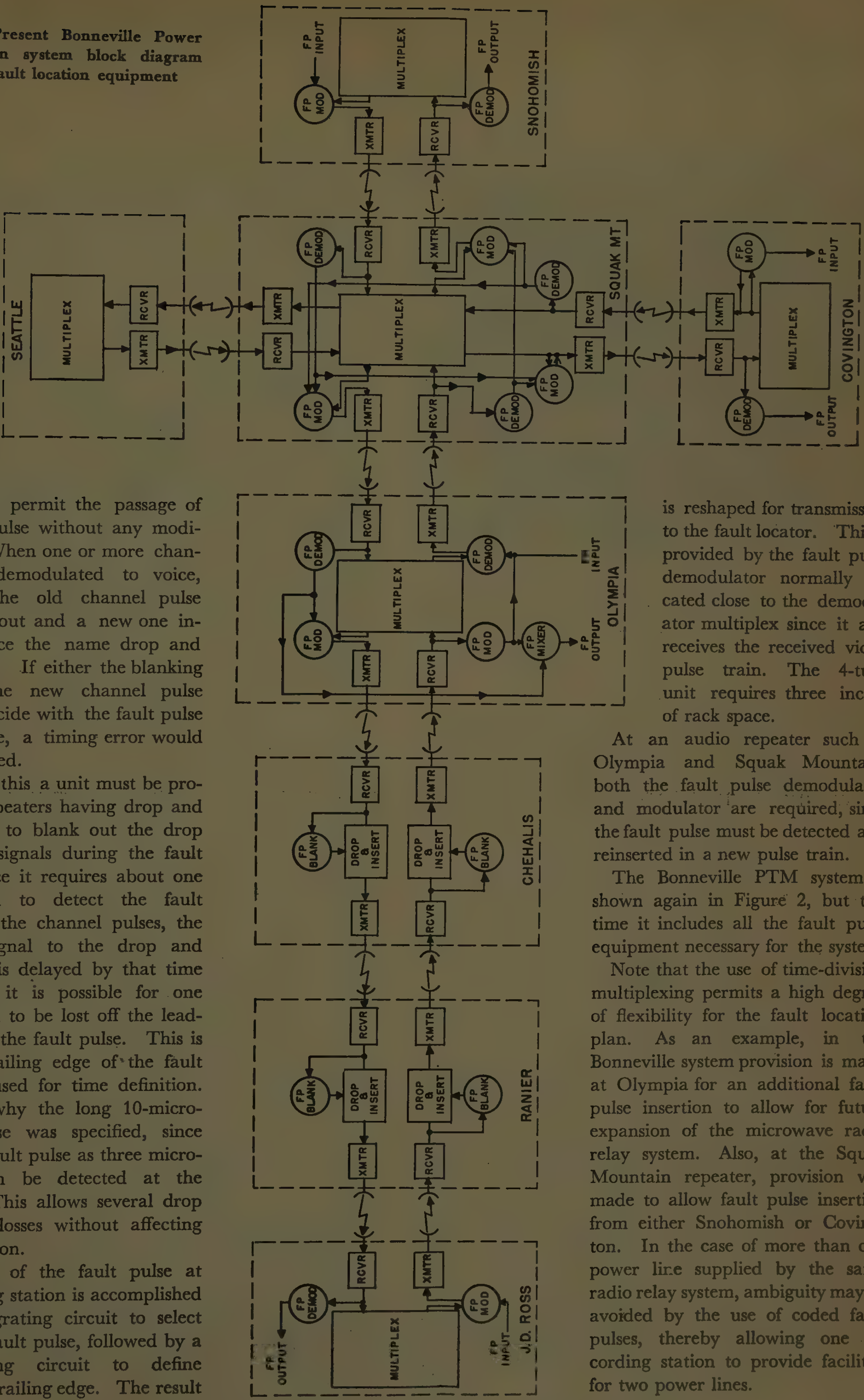
1. Faults produce steep wave fronts which may be detected from the normal power frequencies.
2. The speed of propagation of these wave fronts along a transmission line is constant within a very small percentage.
3. The attenuation of the wave fronts is small enough to allow propagation of the order of several hundred miles, including passage through substations.
4. Available electronic counters are capable of measuring time intervals as small as 0.625 microsecond. Since the speed of propagation is 5.37 microseconds per mile, it is then feasible to measure propagation times corresponding to an accuracy of almost one-tenth of a mile.

The proposed Bonneville Power Administration PTM (Pulse Time Modulation) system is shown in Figure 1. The first portion, now installed, includes the stations: J. D. Ross, Rainier, Chehalis, Olympia, Squak Mountain, Seattle, Covington, and Snohomish. As shown in Figure 2, it consists of a terminal, two video repeaters, an audio repeater, an audio branching repeater, and three terminals. Only eight of the 23 channels are being utilized at present. Over this microwave link, the fault pulse must be transmitted and hence provisions made for supplemental equipment. This equipment and its necessities are described successively in the following paragraphs.

The basic requirement that the PTM radio relay system pass a 10-microsecond pulse with rise and decay time of 0.2 microsecond maximum is permissible with no modification whatsoever, since the band width of the PTM link is greater than necessary to support the fault pulse. Also the PTM pulse train could be interrupted for several hundred microseconds with a barely perceptible effect on voice communication, so no modifications are necessary to avoid interruption of normal traffic. Paradoxically, it is the normal traffic which will affect the fault pulse. To be explicit, the leading or trailing edge of the fault pulse might be displaced in the event a channel pulse of the PTM pulse train occurs at the same time. To avoid this, it is necessary to blank out the pulse train prior to the insertion of the fault pulse. For reasons involving repeater points, the trailing edge of the fault pulse was chosen as the time defining edge. Hence at the insertion point of the fault pulse, the pulse train is blanked out for approximately 15 microseconds, starting simultaneously with the fault pulse, but lasting five microseconds longer to protect the trailing edge. This is accomplished in an 8-tube unit called the "fault pulse modulator," normally rack-mounted adjacent to the modulator multiplex output. It requires five inches of rack space and is provided with two inputs for fault pulses to allow for dual inputs from branching power lines.

By video repeater is meant a repeater wherein the microwave signal is detected as a video pulse train, but no demodulation to voice is provided. The video pulse train simply remodulates the transmitter.

Figure 3. Present Bonneville Power Administration system block diagram showing fault location equipment



This would permit the passage of the fault pulse without any modification. When one or more channels are demodulated to voice, however, the old channel pulse is dropped out and a new one inserted (hence the name drop and insert unit). If either the blanking gate or the new channel pulse should coincide with the fault pulse trailing edge, a timing error would be introduced.

To avoid this a unit must be provided at repeaters having drop and insert units to blank out the drop and insert signals during the fault pulse. Since it requires about one microsecond to detect the fault pulse from the channel pulses, the blanking signal to the drop and insert unit is delayed by that time and hence it is possible for one microsecond to be lost off the leading edge of the fault pulse. This is why the trailing edge of the fault pulse was used for time definition. It is also why the long 10-microsecond pulse was specified, since as short a fault pulse as three microseconds can be detected at the terminal. This allows several drop and insert losses without affecting final detection.

Detection of the fault pulse at the receiving station is accomplished by an integrating circuit to select the longer fault pulse, followed by a differentiating circuit to define sharply the trailing edge. The result is reshaped for transmission to the fault locator. This is provided by the fault pulse demodulator normally located close to the demodulator multiplex since it also receives the received video pulse train. The 4-tube unit requires three inches of rack space.

At an audio repeater such as Olympia and Squak Mountain, both the fault pulse demodulator and modulator are required, since the fault pulse must be detected and reinserted in a new pulse train.

The Bonneville PTM system is shown again in Figure 2, but this time it includes all the fault pulse equipment necessary for the system.

Note that the use of time-division multiplexing permits a high degree of flexibility for the fault locating plan. As an example, in the Bonneville system provision is made at Olympia for an additional fault pulse insertion to allow for future expansion of the microwave radio relay system. Also, at the Squak Mountain repeater, provision was made to allow fault pulse insertion from either Snohomish or Covington. In the case of more than one power line supplied by the same radio relay system, ambiguity may be avoided by the use of coded fault pulses, thereby allowing one recording station to provide facilities for two power lines.

High-Impedance Control Source for Saturable Reactor

H. F. STORM
MEMBER AIEE

THIS ANALYSIS is based on core materials whose magnetic property can be approximated by a rectangular flux-density field-intensity curve. The control source is considered of high impedance when alternating currents are practically nonexistent in the control circuit. This condition is encountered in practice in saturable reactors used for the measurement of large direct currents, and also in the constant-current standard where the d-c control winding is replaced by a permanent magnet.

Figure 1 shows the circuit diagram. In order to simulate a high impedance for the control source voltage E_C, the reactor L_C is placed in series with it. No voltage of fundamental frequency or odd harmonic appears across L_C by virtue of the circuit connections. In order to suppress sufficiently the remaining even harmonics in the control circuit, the reactance of L_C should be at least 100 times the value of the load resistance; this reactance is based on the second harmonic and is referred to the load resistance R_L by the square of the turns ratio.

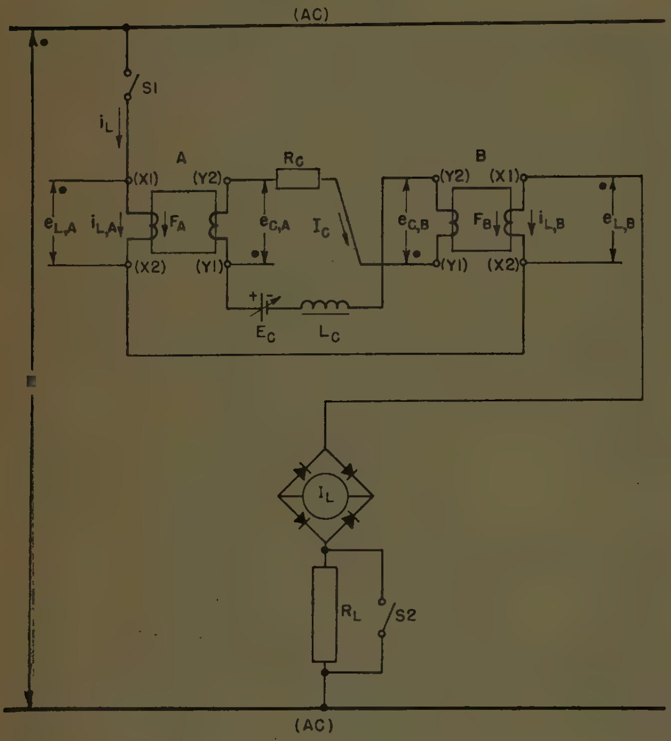


Figure 1. Schematic diagram of saturable reactor circuit, consisting of two single-phase transformers A and B

Depending on the various parameters such as supply voltage, load resistance, and control current, eight different modes of operation are encountered, of which the first mode is of greatest practical importance. In this mode the load current has a square wave shape (Figure 2). When rectified, the load current is nearly a perfect direct current, requiring no filtering in many instances. Linearity exists between control current and load current

$$I_L N_L = I_C N_C \qquad (1)$$

I_L is the average value of the load current, I_C the control current, N_L denotes the number of turns of the load winding ($X1$, $X2$), and N_C is the number of turns of the control winding ($Y1$, $Y2$). Exception to equation 1 occurs in the vicinity of zero control current; the load current does not become zero because this requires infinite impedance of the saturable reactors A and B, which cannot be realized. There is also an upper limit for this equation at which the boundary between mode 1 and mode 2 is reached.

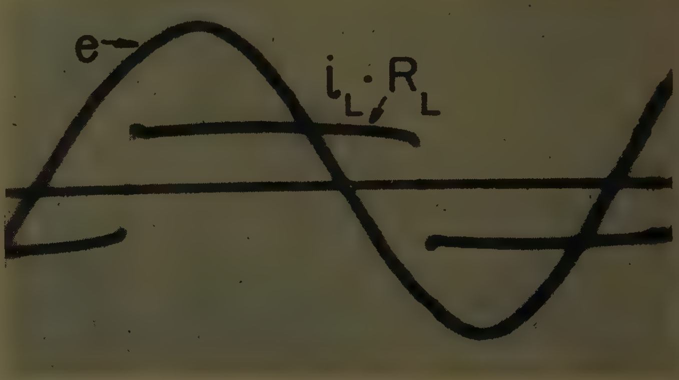


Figure 2. Oscillogram of the supply voltage e and the voltage across the load resistance $i_L R_L$ for mode 1 operation

Within mode 1, a-c line voltage variations and frequency variations have very little effect on the magnitude of the load current. An increase in load resistance merely advances the phase angle of the rectangular current wave but hardly decreases the magnitude of the load current. A sudden change of control current causes an instantaneous proportional change in load current.

Because of these properties the circuit can be used very advantageously to measure large direct currents without the use of shunts. By replacing the magnetomotive force of the control windings by a permanent magnet, a constant-current standard is obtained. Furthermore, by energizing a constant resistance from the constant-current standard, a constant-voltage standard is derived. Considering the character of the circuit components, one may expect low maintenance, high shock resistance, and long life expectancy.

Digest of paper 50-205, "Series-Connected Saturable Reactor With Control Source of Comparatively High Impedance," recommended by the AIEE Committee on Electronics and approved by the AIEE Technical Program Committee for presentation at the AIEE Middle Eastern District Meeting, Baltimore, Md., October 3-5, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Tube-Type Totally Enclosed Fan-Cooled Motors

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OPERATING ECONOMIES are obtained from the use of totally enclosed fan-cooled motors. Power companies employ them outdoors to reduce building costs, and both power companies and industry use them to lower maintenance costs and outages in locations where motor-cooling air might be dirty, dusty, or otherwise unsatisfactory for direct contact with the windings or internal parts of a motor. Where the use of air only as a cooling medium is preferred, the totally enclosed fan-cooled motor with cooling tubes built into the frame finds wide application (see Figure 1).

Important design objectives are an efficient cooler and an effective enclosure. The objectives are not independent of each other. It is important to co-ordinate efficient removal of heat losses with effective enclosing of the motor.

Both National Electrical Manufacturers Association[1] and American Standards Association[2] standards state the temperature rise of class-*A*-insulated totally enclosed fan-cooled motors is 55 degrees centigrade, by thermometer, or 60 degrees centigrade, by resistance. If the ambient or room air is 40 degrees centigrade the total motor temperature is 95 degrees centigrade, by the thermometer method. The tube-type class-*A*-insulated motor is essentially a 40-degree centigrade rise motor supplied with 55-degree centigrade cooling air from the heat exchanger.

Totally enclosed motors require special attention to the problem of removing heat losses. Increased motor size is not an economical solution to obtain the necessary surface area required for removing the losses. A particular design which provides the proper area is the tube-type air-to-air heat exchanger, referred to as a tube-type cooler, which is built directly into the motor itself. Enclosure problems are those arising principally from the clearance required between rotating and stationary members and where parts are joined.

In the tube-type motor the space between the back of the stator punchings and the wrapper or cover plate of the machine is occupied almost entirely by the tubes which run parallel to the shaft. The ends of the tubes are rolled in holes drilled in the frame end plates so that the tubes become an integral part of the motor frame. Tubes are arranged to obtain maximum heat exchange effectiveness and are staggered to promote turbulence of the air passing through the cooler.

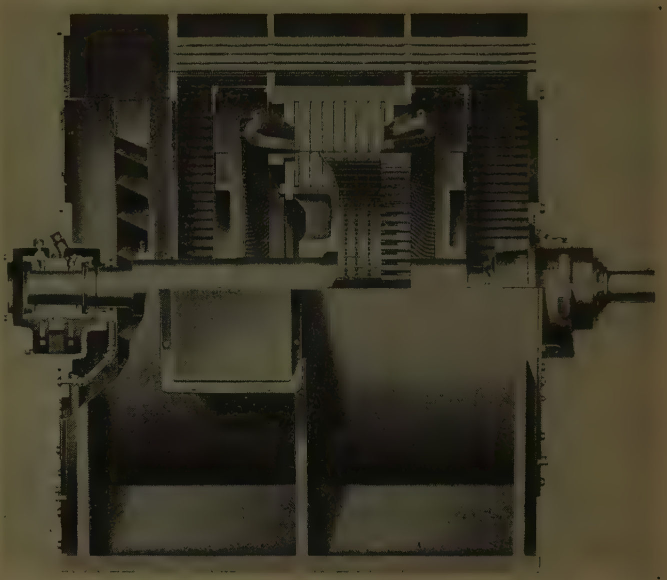

Figure 1. Section view of totally enclosed fan-cooled squirrel-cage induction motor of tube-type heat exchanger construction

To prevent ambient or room air from entering readily into the interior of the motor, careful attention is given to shaft seals, parting joints, and so forth. On low-speed machines the shaft seal is made of felt, which rubs on the shaft. On high-speed machines there is a very small clearance between the stationary seal and the rotating shaft to avoid local heating which a rubbing seal would develop. Housing partings, joints, and so forth, are thoroughly sealed at assembly. Cleaning of the inside of the tubes can be easily done by a brush while the motor is in operation, if desired.

If possibilities of moisture being taken into the motor exist because of breathing action, space heaters can be provided inside the motor.

During the past five years over 60,000 horsepower of both horizontal and vertical induction motors have been built with air-to-air tube-type heat exchangers. Motor ratings and speeds of installations range from 1,250 horsepower at 3,600 rpm, cage type, to 350 horsepower at 333 rpm, wound-rotor type. The temperature rise applications range from 40 degrees centigrade for class-*A* insulation to higher temperature rises permissible for class-*B* or class-*H* insulation.

There appears to be no upper limit of size or commercial application of tube-type motors. They are more expensive to build than splash-proof or air-to-water cooler types. However, the over-all evaluation must be made keeping in mind many factors such as cost of maintenance, importance of outages, dust or dirt conditions, possibility of steam leaks, and the like.

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Digest of paper **50-228**, "Large Tube-Type Totally Enclosed Fan-Cooled Motors," recommended by the AIEE Committees on Power Generators and Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–27, 1950. Not scheduled for publication in AIEE *Transactions*.

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Lepeth Sheath for Telephone Cables

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A new telephone cable sheath design has been developed by the Bell Telephone Laboratories in co-operation with Western Electric engineers. This sheath structure consists of a polyethylene jacket extruded on the cable core, over which a relatively thin lead sheath is applied. This design provides a high degree of protection against cable damage by lightning, and its adoption has resulted in a reduction in costs.

SINCE the introduction of lead-covered telephone cable, there have been many improvements in the methods of applying this protective sheath. However, until recently, the only significant changes in the basic design of the sheath had been in the composition of the alloy used.

The standard lead-sheathed cable construction (Figure 1) consists simply of a core of insulated conductors over which the lead is extruded. Based on the results of extensive field tests, a schedule of lead-sheath thicknesses has been evolved. The thickness of the lead applied is primarily governed by the cable core diameter and also is influenced by the type of armor, if any, which is to be provided. The sheath is conventionally produced by passing the core through a ram-type extrusion press. Many different sheathing alloys have been used from time to time, but the material which has been almost universally adopted in the Bell Telephone System contains, as its primary alloying element, one per cent of antimony. This lead alloy is characterized by its relatively high tensile strength and resistance to fatigue. This latter quality is of especial importance in aerial and duct cables, since the stresses which are most likely to cause sheath failure in these cables are oscillatory in nature and result in fatigue failure. These stresses are set up in aerial installations where the cable is attached to a pole and in ducts where it enters a manhole. Of course, fatigue resistance is of much less importance in buried installations.

Subsequent to World War II, the greatly increased requirements for lead, together with the difficulties incident to importing this material, caused its supply to become critically short. This shortage provided an incentive for the adoption of lead-sheath substitutes. The first of these new sheath designs to be adopted for widespread use on buried toll cable was a composite lead and polyethylene structure which became known as "lepeth" (Figure 2).

In this construction a 0.075-inch jacket of polyethylene is first extruded over the paper-wrapped core. The jacketed cable is then flooded with thermoplastic cement, over which a lead sheath is applied. Since toll cables are generally kept under gas pressure, the thermoplastic cement serves as a seal between the polyethylene and the lead to prevent axial gas flow between the two in case a leak should develop in the lead. Likewise, if a hole should be made in the lead, the area of polyethylene which would be exposed to moisture and, consequently, the rate of diffusion of moisture into the cable, would be held to a minimum.

With the removal of wartime government controls from the lead market, this material became much more readily available. Although the lepeth design was first employed because of an acute lead shortage, the use of this new sheath has continued because of the high dielectric strength between core and metal sheath and the greater reliability of a double-barrier sheath.

MANUFACTURING PROCESS

THE LEPETH-SHEATH manufacturing facilities consist of a commercial plastics extruder, a thermoplastic cement applicator, and a continuous-type lead extruder operated in tandem (Figure 3). When the cable cores are ready for sheathing, they are dried in the conventional manner and placed in a heated room at the supply end of the line. This room is designed to accommodate two cable-core trucks, thus permitting the replacement of one truck, when empty, while sheathing cable from the other. As the end of one cable is reached, it is secured to the leading end of the next by suitable hooks, making the operation continuous with the minimum of scrap being formed between cables.

The plastics-extruder portion of the line consists of a supply capstan, the extruder proper, a cooling trough, and a take-up capstan. The capstans are of the tractor type. In this case, the driving members are chains, sprocket-driven to prevent slipping, with molded rubber shoes attached to grip the cable. Each capstan is powered by a $1^1/_2$-horsepower d-c motor which is driven from a small motor-generator set. Speed control is obtained by varying the generator excitation.

The polyethylene extruder is a standard commercial model with an $8^1/_2$-inch-diameter screw. This machine is driven through a multiple V-belt drive by a 150-horsepower d-c motor. This motor is also connected to a motor-generator set, and it is controlled by varying the generator excitation.

To provide means of maintaining synchronism between the two capstans, a dancer roll is installed in the cooling trough. Should any speed differential exist between the capstans, the catenary formed by the cable in the trough would either rise or fall and the dancer roll would move accordingly. This movement is caused to vary the position

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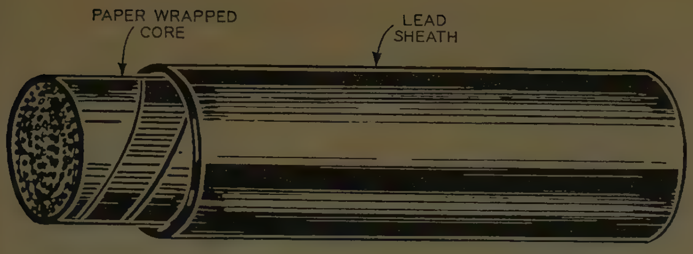

Figure 1. Standard lead-sheathed cable with a core of insulated conductors covered by an extruded lead sheath

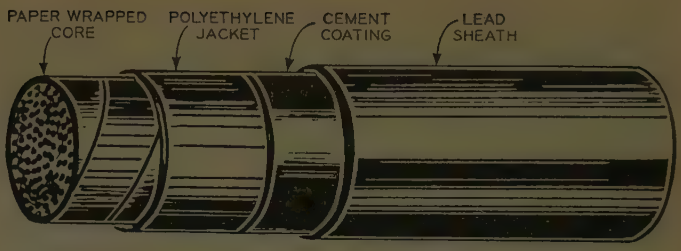

Figure 2. Lepeth composite lead-sheathed cable. The cement acts to prevent an axial flow of gas between lead and polyethylene

of a rheostat which, in turn, changes the speed of the supply capstan in such sense as to restore synchronism. A second rheostat is ganged with the one just described, and its movement varies the speed of the extruder drive motor. Therefore, any change in speed of the cable being jacketed is accompanied by a proportionate change in the speed of the extruder screw. Within the limited speed range over which these dancer-roll rheostats operate, this system of making screw speed changes proportional to cable linear speed changes provides essentially constant volume of plastic per unit length of cable.

The next major unit in the line of equipment is a supply capstan for the lead-extrusion machine. This capstan is identical mechanically to the two capstans associated with the plastics extruder.

The lead-extrusion machine is of the continuous type and was procured from the Pirelli-General Cable Company, Ltd., of Southampton, England.

The conventional method of making a lead sheath is by means of a hydraulic press. This type of press consists of a cylinder which is filled with molten lead and a ram which applies pressure to the lead after it has been allowed to cool below its melting point. The lead, which is then in a plastic state, is forced through dies at the other end of the cylinder in the form of pipe. This method of forming a lead sheath has several disadvantages:

1. It is intermittent, as it is necessary to charge the cylinder with lead and then allow sufficient time for the lead to cool into a plastic state.

2. Each time extrusion of the lead is stopped, a press mark at the die results. This mark is a ring somewhat similar in apppearance to a bamboo joint and constitutes a weak spot in the sheath which may crack when flexed during reeling and unreeling operations.

3. Oxides may be included at the junction of a new charge and the preceding charge.

4. The thickness of the sheath varies slightly from the beginning of a charge to the end because of temperature changes during the cycle, making it necessary to use a slightly thicker lead sheath than specified so as to insure proper thickness at all times.

5. Since it is necessary for the lead stream to divide to flow around the extrusion tools, a continuous weld is formed along one side of the sheath. Occasionally, a poor weld is formed and this results in a serious sheath defect, commonly called split sheath.

The introduction of a plastic material as a cable-sheath component has made it necessary to use a press which can extrude a thin lead sheath of uniform thickness and diameter continuously. If the press is stopped for charging with a cable in it, the plastic covering next to the dies will melt. It has, therefore, been necessary to use a continuous-extrusion machine if economical shipping lengths, which usually require more than one charge, are to be manufactured.

The Pirelli press has proved itself to be an answer to this problem. A brief description of this machine is as follows. Numbers refer to Figure 4. The rotating hollow screw *1* has both internal and external threads. The barrel surrounding the screw is shown as *2* and the stationary center as *3*. The molten lead flows through the electrically heated pipe *4* and enters both the internal and external threads of the screw. The barrel and stationary center are chilled by passing water through a series of channels *5*.

The molten lead, as it advances with the advancing screw, becomes chilled as it approaches the cooled areas in the barrel and the stationary center. It will be noted that the barrel and stationary tube have longitudinal grooves *6*. As the lead solidifies, these grooves act as keyways to prevent the lead from turning with the screw. The lead therefore acts as a nut on the screw and advances toward the front of the barrel *8* as the screw rotates. It is forced through a spider *7* which supports the dies concentrically. The lead is extruded between these dies and emerges as a pipe where it is immediately chilled with water to prevent

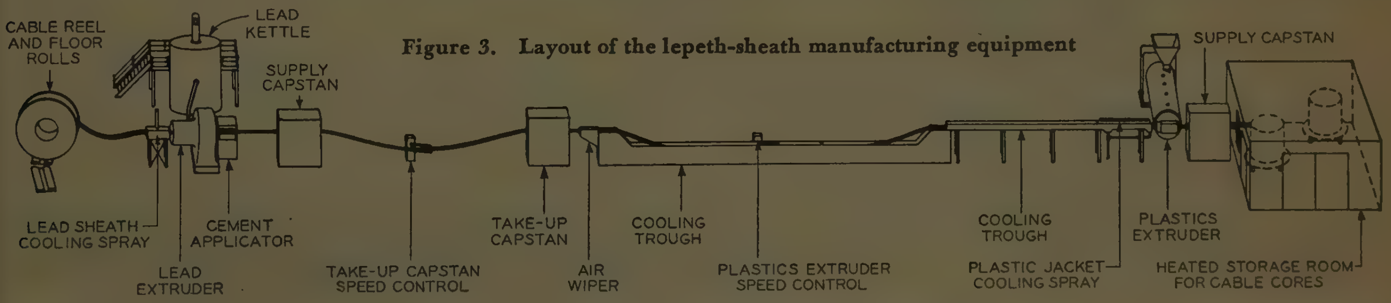
CABLE REEL AND FLOOR ROLLS
LEAD KETTLE
SUPPLY CAPSTAN
SUPPLY CAPSTAN
LEAD SHEATH COOLING SPRAY
CEMENT APPLICATOR
LEAD EXTRUDER
TAKE-UP CAPSTAN SPEED CONTROL
TAKE-UP CAPSTAN
AIR WIPER
COOLING TROUGH
PLASTICS EXTRUDER SPEED CONTROL
COOLING TROUGH
PLASTIC JACKET COOLING SPRAY
PLASTICS EXTRUDER
HEATED STORAGE ROOM FOR CABLE CORES

Figure 3. Layout of the lepeth-sheath manufacturing equipment

the heated lead from melting the plastic sheath under it. The thickness of the sheath can be varied by means of the die adjusting nut *9*.

In starting the press it is necessary to preheat the barrel to soften the lead, thus permitting the screw to be turned. This heating is done electrically by three induction coils *10*. Two of these coils are de-energized after the machine has been started and the cooling water is circulated through the cooling channels *5*. The induction coil nearest the lead inlet remains on while the machine is in operation to prevent the lead from freezing before it enters the screw.

The cable core is introduced into the rear of the press and, after passing through the hollow inner die or core tube *11*, emerges with the pipe formed around it as a sheath, the lead being extruded through the opening formed between dies *11* and *12*.

The drive equipment for the lead-extrusion machine is similar to that for the plastic extruder and consists of a 200-horsepower d-c motor driven by a motor-generator set. An electronic exciter and regulator control the field of the generator, thereby controlling the generator voltage and, in turn, the speed of the d-c motor. To protect the reduction gearing in case the machine is started before it has been brought up to operating temperature, a torque-limiting feature has also been incorporated in this drive. During normal operation, the regulator receives its signal from a tachometer generator on the motor shaft. However, it has an additional input which consists of a voltage developed across a shunt in the d-c-motor armature circuit. This voltage is proportional to the armature current and, therefore, to the motor torque. When it reaches an adjustable, preset value, this torque signal assumes control of the regulator causing it to disregard the tachometer signal and reduce the generator field excitation until the torque limit requirement is satisfied. This feature is incorporated as a safety device. Since it provides a positive means of limiting the torque applied to the machine, it prevents the excessive mechanical stresses which might otherwise be developed if an attempt should be made to start the extruder under other than normal operating conditions; that is, with the temperatures in the barrel below the desired values.

It has been found that considerably higher extrusion speeds can be obtained with the Pirelli machine when extruding an alloy of lead and silver than with the conventional lead-antimony alloy. The alloy used is formed by the addition of about 0.01 per cent of silver to commercially pure or "corroding" grade lead. This material offers an additional advantage in that its creep characteristics are superior to those of lead-antimony and it has adequate tensile strength and fatigue characteristics for buried installations. Since the principal stress in the sheath on a buried cable is the low-intensity steady stress resulting from the internal gas pressure, the lead-silver alloy is particularly well suited for use in this type of installation.

The sheathing alloy for several lead-extrusion machines is prepared and distributed by means of a central lead-melting system. The lead is melted and the alloy mixed in a 55,000-pound kettle. It is then pumped to the 20,000-pound holding kettle located near each lead extruder. From each holding kettle the lead is allowed to flow by gravity into the barrel of the associated Pirelli machine. The kettles are oil-fired, and the molten-lead circulating and distributing pipe lines are heated by passing an electric current through the pipes.

Because of the interrelation of torque requirement, degree of cooling, and screw speed in the Pirelli machine, its extrusion speed cannot be varied quickly and simply during the sheathing process. Therefore, the speed of this machine has been made the independent variable in tandem operation and such random speed variations as may develop and tend to destroy the synchronism of the line of machines are compensated for by changing the speed of the plastics extruder, its associated capstans, and the supply capstan for the lead extruder.

The lead-extruder supply capstan is powered by a d-c motor with an electronic rectifier and regulator, the combination having adjustable constant-torque characteristics. This type of drive is provided to insure against any drag being exerted on the cable as it passes through the lead extruder. For any given cable design, a certain torque is required to balance the tension which is due to the weight of the catenary formed between this capstan and the take-up capstan of the plastics extruder. Since the level of the catenary varies only slightly during operation, this tension and, consequently, the torque required may be considered as constant for each type of cable. The drive equipment is adjusted to provide a torque slightly greater than that required to support the catenary. The differential torque is

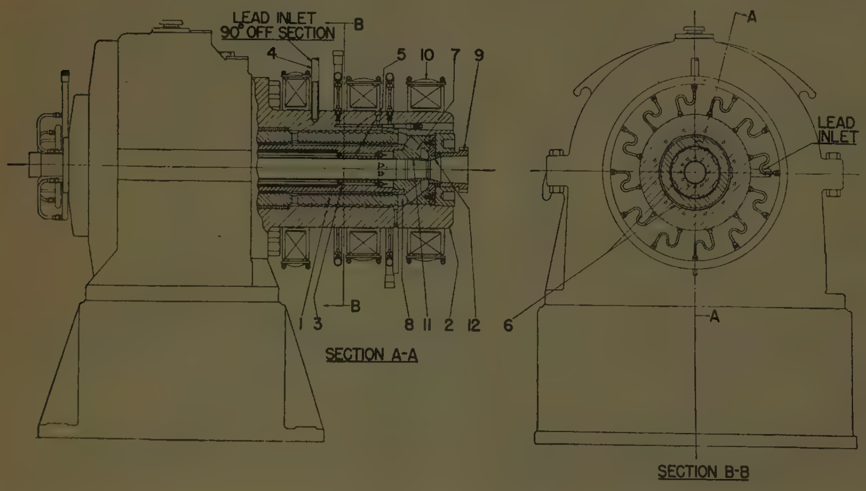

Figure 4. The Pirelli press makes it possible to extrude continuously a thin sheath of lead with uniform thickness and diameter

exerted as a controlled push on the cable as it enters the lead extruder and, therefore, the cable speed conforms to the lead-extrusion speed and the possibility of any drag is eliminated.

Between the plastics-extruder take-up capstan and the lead-extruder supply capstan, the cable forms a shallow loop or catenary and supports a dancer roll. This dancer roll operates a rheostat, according to the level of the loop; the rheostat, in turn, varies the speed of the extruder take-up capstan to compensate for the error in cable position. Thus, any variation in speed of extrusion of the Pirelli machine is followed by a change in the speed of this take-up capstan. Any such speed change is followed by a change in the speed of both the extruder and its supply capstan through the operation of the dancer roll in the cooling trough as previously explained.

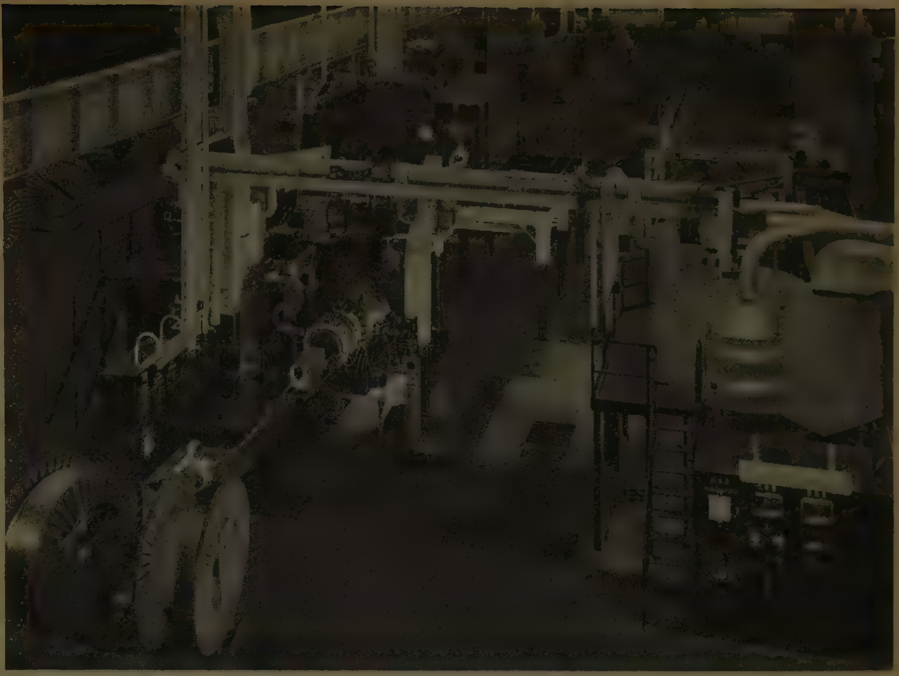

Figure 5. The manufacturing line for the lepeth sheath with the lead kettle in the right foreground

After sheathing, the cable is taken up on a reel resting upon a pair of driving rolls set in the floor. To permit continuous tandem operation with successive cable lengths closely coupled, it is necessary to provide means for rapidly shifting from one take-up reel to another after the lengths have been cut apart. This is accomplished by placing two sets of reeling floor rolls in a fanned arrangement in front of the Pirelli lead extruder. While one cable is being reeled on one set of rolls, the other set is cleared and an empty reel is placed in reeling position. Thus, when two lengths are separated the leading end of the new length is fastened to this empty reel and this cable is taken up without interruption.

In addition to the varied electrical tests which are given all toll cables, lepeth cables are subjected to a high-voltage breakdown test to insure against defects in the polyethylene jacket. In this test, a potential of 20,000 direct volts is impressed from core to lead sheath. Because of the presence of this insulating layer with its proved high dielectric strength, the lead sheath can be relied upon to dissipate large electric charges, such as are created when lightning strikes near the cable, without serious risk of damage to the cable conductors.

APPLICATION

Lepeth cable is provided with one of several different types of outer protective coverings, the type specified depending upon the service conditions expected. To take advantage of the lightning-protection possibilities of the lepeth sheath and, at the same time, to provide the necessary mechanical protection for the cable, a new type of armor was developed. This new protective covering is referred to as modified tape armor, abbreviated *MTA*. This outer protection consists of a layer of 0.010-inch lead tape alternated with 0.012-inch fiber-reinforced paper tape, a layer of 0.010-inch steel tape, and an outer layer of two 0.020-inch steel tapes wound with one covering the gap between turns of the other. The lead and paper tapes protect the lead sheath from damage by the steel tapes during handling.

A covering of one or two layers of jute is applied over the outer steel tape and a flooding of asphalt compound is applied over each serving of tape and jute as a preservative for these materials. Tests have shown that the asphalt does not destroy the electrical contact between the several metal tapes and the lead sheath. Therefore, the high voltage set up in the steel tapes by nearby lightning strokes may be discharged into the lead sheath and the charge dissipated through both the sheath and armor without the formation of damaging explosive arcs.

Investigations conducted by the Bell Telephone Laboratories indicate that in areas of low to medium soil resistivity the combination of lepeth sheath and *MTA* is adequate protection against lightning strokes. This is based on the fact that the polyethylene jacket is subjected to the factory breakdown test of 20,000 direct volts, approximately the equivalent of a 28,000-volt impulse voltage as encountered in lightning discharges. In the relatively rare instances of very high soil resistivity, this protection is supplemented by the installation of copper shield wires a few inches above the cable when it is plowed into the ground.

CONCLUSION

The early manufacture of lepeth-sheathed cables was done using temporary facilities and required that the polyethylene and lead components be applied in separate operations. Installation of the equipment which has been described in this article has been completed and this continuous tandem process is now being used for commercial production.

Copper-Fin Totally Enclosed Motors

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FOR MOTOR APPLICATIONS where the air is contaminated with dust, the totally enclosed motor has proven worth while in reduced maintenance. In the past five years, totally enclosed fan-cooled a-c motors have become available in ratings above 500 horsepower, opening up many applications in powerhouse auxiliaries and mill uses where dirty air is a problem.

Totally enclosed motors above 300 horsepower have in the past been difficult to cool, due to the fact that outside surface per unit of volume is less and the distance the heat has to be conducted is greater in the larger motor. Numerous attempts have been made to provide additional surface for transferring heat between the internally circulated air and the external air. This usually has resulted in excessive size or costs. In looking for a better answer to the problem, the authors considered that a much more effective method would be to conduct the major part of the heat to the outside. This led to the idea (United States Patent Number 2,482,491) of copper punchings stacked between the iron laminations and extending out about two inches at the back of the core to form the required heat-dissipating surface and to provide excellent heat conductivity in the radial direction.

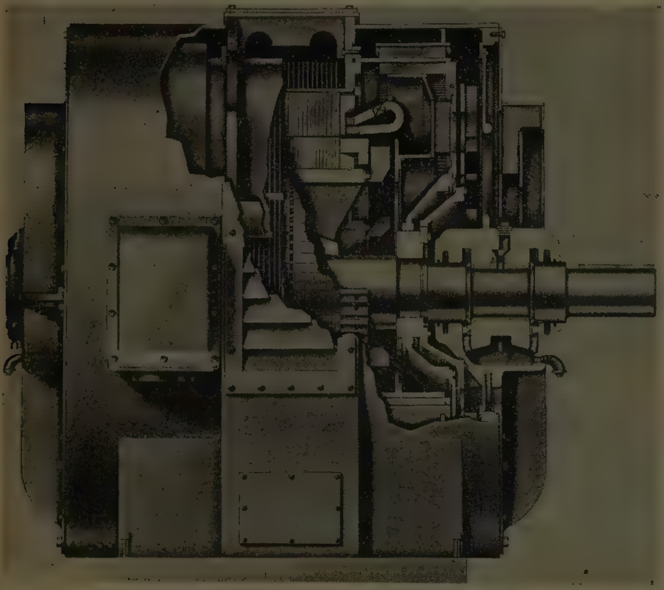

Figure 1. Cross-sectional view of a copper-fin totally enclosed motor

In addition to copper fins projecting from the back of the core, cylindrical enclosing end bells are provided with copper fins projecting through slots in the cylindrical wall. Removable baffles, which can be seen in Figure 1, are added over the copper fins between end plates to take air from the frame and guide it along the fins to the air exits. Addition of frame cover and feet complete the core assembly.

Referring again to Figure 1, it will be noted that there is an internal and external air-circulating system. The internal air, circulated by blowers mounted on each end of the spider arms, carries heat from the coil extensions and some from the rotor to the internal finned surface of the cylindrical heat exchangers. The external cooling air is drawn in at each end of the motor by shaft-mounted blowers. This provides cool bearings even for class-*H* motors. Air then is forced over the external finned surface of the heat exchanger and through holes in the frame rings into the outer frame enclosure. Air from this enclosure is baffled and enters the copper fin at the top and bottom of the core. It then divides and traverses one-quarter of the core periphery to discharge openings on each side of the motor.

The first application of such motors was made five years ago in a rubber mill where other motors were giving trouble because of the excessive amount of lamp black associated with the new synthetic rubber program. This motor was a 450-horsepower 2-speed motor, and with class-*B* insulation it was put in the same mounting dimensions as the open motor of the same rating. Several hundred motors of the copper-fin type now are in operation with ratings from 125 to 1,000 horsepower, and give excellent service. Most of these are of the squirrel-cage type, but a number are wound-rotor induction motors and synchronous motors.

This design is particularly well suited to moderate- and low-speed designs. For eight poles and above it is practical to build motors rated 2,500 horsepower and higher. Up to 1,000 horsepower the class-*H* enclosed motor requires no more space than a class-*A* open motor. At 1,800 rpm, a 900-horsepower motor has been designed and a larger horsepower motor could be built. For 3,600 rpm, the depth of core is so great that it makes this type of design less desirable than the heat-exchanger type.

This type of motor is well adapted to applications in power stations, steel mills, cement mills, flour mills, and grain elevators. In fact, it is suitable for any indoor application where dust and dirt are excessive for speeds up to 3,600 rpm. The design is not explosion-proof but can be made to meet the Underwriters' class-II conditions for grain, metal, and carbon dust.

It is believed that the copper-fin motor provides the most compact design of totally enclosed motor which can be readily cleaned. This design has proved very reliable and many large motors of this type will be used in the future.

Digest of paper 50-260, "Copper-Fin Totally Enclosed Motors," recommended by AIEE Committees on Power Generation and Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23-7, 1950. Not scheduled for publication in AIEE *Transactions*.

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Tracking Radio Noise on Aircraft

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RADIO NOISE INTERFERENCE reduction methods for use in aircraft have not received adequate attention in recent years. Almost complete reliance is placed on equipment covered by military specifications, in spite of the fact that little or no equipment meeting the specifications is available. The work of the radio interference engineer can never be economically eliminated, despite all possible improvements in equipment, and therefore suppression methods must be available.

As a means of understanding the method of radio interference generation, it is proposed that the generator be looked upon in a manner similar to that used toward a cavity resonator of very low *Q*. The cavity, in the practical case a motor or magneto, is excited by an impulse source such as commutation in the motor, and opening of the breaker points in a magneto. Since the impulse is in the form of a square wave of short duration, the cavity is excited in all odd harmonics of the fundamental. Even though the cavity considered is small internally, the iron, copper, or other metals filling the cavity tend to make it broadly resonant over a wide frequency range, as well as to lower the resonant frequency. Large currents flowing on the inner walls of the cavity flow outside the cavity at an opening or crack. These currents flowing outside the cavity form a local field at the location of the opening, see Figure 1. This field may be detected by means of a loop probe and a standard very-high-frequency noisemeter. With a very small probe, for instance, a loop with a 3/4-inch diameter, small fields may be located accurately.

Two methods of utilizing this concept are available. In the first, a portable signal generator operating around 150 megacycles feeds a signal into the ignition harness of an aircraft engine. A spark plug lead is removed, and the signal injected there. A portable receiver, strapped to the operator, is employed with a small loop to probe for leaks in the harness, such as broken flexible leads, loose joints, and ill-fitting magneto covers. By means of this apparatus, an aircraft engine can be quieted in a few minutes, since the faults can be located very quickly and all that is necessary in most cases is tightening down. The apparatus is constructed for operation by flight-line personnel and is extremely simple to operate because it requires no knowledge of radio theory or practice. Figure 2 shows the apparatus in use.

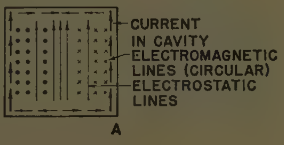
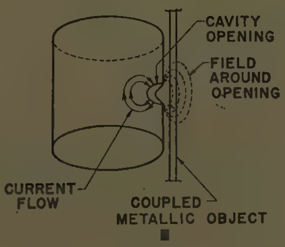


Figure 1. (A) Field configuration inside a resonant cavity.



(B) External field about a break in a resonant cavity showing coupling to proximate metallic objects

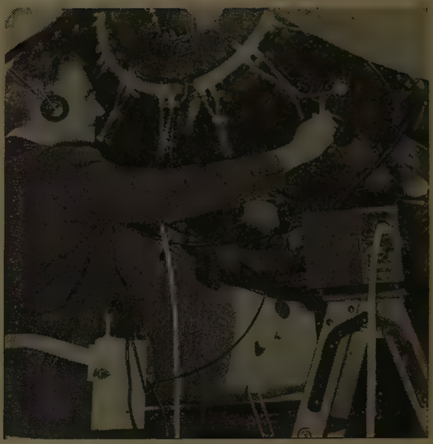


Figure 2. Very-high-frequency signal injection and detection equipment in use on airplane engine

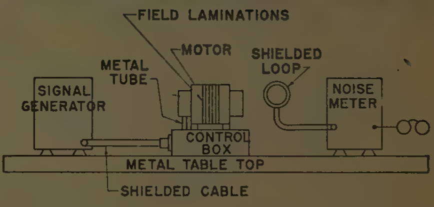


Figure 3. Laboratory setup for field determinations about an electric motor

The second method is used on a motor or other device which may be mounted in close proximity to a piece of radio apparatus or an open wire lead-in, or even within radio apparatus. Figure 3 shows a laboratory setup for this test. A signal generator or the device described in the preceding paragraph may be used to inject a signal onto the device under test, and the points of leakage found with a noisemeter or the portable receiver. On a typical motor, very intense fields were found around the field laminations, indicating heavy radio-frequency currents flowing there. Other points were found to be a metal tube carrying wiring between the motor and the control box. Shielding and bonding as necessary eliminated the fields, and resulted in a motor that was very quiet, after being fitted with an appropriate filter. Previous operation, even with the filter, had produced intolerable interference.

The following conclusions have been drawn about this equipment: (1) the test methods shown are particularly adaptable for the elimination of radio noise from aircraft engine ignition systems; (2) where it is necessary to provide very close shielding for a piece of electric apparatus, the injection method is both simple and sure.

Digest of paper 50-196, "Tracking Radio Noise on Aircraft," recommended by the AIEE Committee on Air Transportation and approved by the AIEE Technical Program Committee for presentation at the AIEE Middle Eastern District Meeting, Baltimore, Md., October 3–5, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Design of Broad-Band Transformers for Linear Electronic Circuits

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This article explains certain techniques developed by the transformer designers of the General Electric Company for shortening the time required to design and develop transformers which meet the highly specialized needs of electronic engineers. It places particular emphasis on the design of broad-band audio transformers.

WHEN DESIGNING LINEAR amplifier circuits, the designers often find it highly desirable to take advantage of the impedance-matching and phase-inverting properties of transformers. However, these designers sometimes fail to realize that even a well-designed transformer may not be able to pass the required band of frequencies when connected between the available power source and specified load. At other times they may ask for impedance or phase characteristics which are unrealistic or which call for unnecessarily close tolerances.

The designers of the transformers which electronic circuit designers need do not always appreciate the manner in which certain transformer characteristics influence the over-all frequency response of the combined transformer and linear-amplifier circuit. Another little known factor is the manner in which the transformer contributes to the harmonic distortion.

So long as the electronic circuits were required to handle bandwidths of only a few kilocycles, this lack of understanding was not serious. However, the advent of high standards of performance for both amplitude-modulation and frequency-modulation transmitters and studio equipment soon made this difficulty very apparent. The electronic circuit designers complained that it was very difficult to obtain completely satisfactory transformers for their equipment. They almost invariably had to go through a long series of developmental samples on small units before obtaining satisfactory transformers. On the larger modulation transformers, they usually had to incorporate a series of compensating and equalizing networks in their circuits in order to obtain satisfactory over-all performance. On the other hand, the transformer designers complained that the specifications given them by the electronic engineers were often incomplete or unrealistic. Furthermore, they claimed that their designs would often test satisfactorily in the low-power or equivalent test circuit specified by the electronic engineers and then give unsatisfactory performance under actual operating conditions.

This state of affairs was brought to the attention of the author in the early part of 1947. A review of the pertinent literature available at that time[1,2] revealed no really satisfactory answer to the general problem, so a project directed toward rectifying this condition was initiated in the General Electric Research Laboratory. A book[3] published several months later covers this subject fairly well. However, the approach to the problem to be described here offers some advantages over that described in these references. One of the objectives of this project was to provide some common meeting ground between electronic-circuit engineers and transformer-designing engineers. Information was to be provided which would enable the designers of broad-band linear amplifier and transmission circuits to determine the practicability of using transformers to obtain certain desired results and to make proper and realistic requirement specifications to convey their needs to the transformer designer. Also, the information was to be such as to enable transformer designers, given these requirement specifications and electronic circuit operating conditions, to determine the feasibility of designing the required transformers and to predict with reasonable accuracy the performance of the transformers when combined with the circuits.

DEVELOPMENT OF A TERMINOLOGY

PERHAPS the main barrier to the free exchange of information between these two groups of engineers has been that of terminology or language. For example, the electronic-circuit designers use such terms as coefficient of coupling, primary inductance, secondary inductance, and circuit Q to express some of the characteristics of trans-

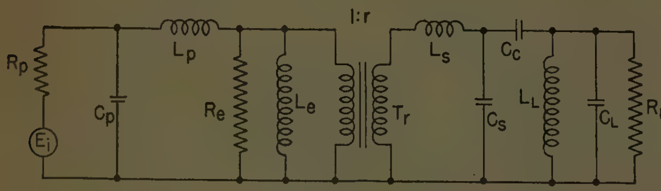

Figure 1. General equivalent circuit of modulator output amplifier, modulation transformer, coupling network, and load

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formers in electronic circuits. Since most audio and power transformers have very tight coupling between the primary and secondary, it is more convenient for the transformer designers to express these characteristics in terms of leakage inductance, magnetizing inductance, and load resistance.

In order to have the analysis cover the most general case, the transformer-coupled modulator with shunt-feed reactor was chosen as representative, since it requires consideration as a coupling network at both ends of the passband.

Figure 1 is the general equivalent circuit of such a modulator, where

E_i = voltage generated in plate circuit of final amplifier tube
R_p = plate resistance of final amplifier tube
C_p = total primary shunt and distributed capacitance
L_p = primary leakage inductance
R_e = equivalent resistance corresponding to core losses
L_e = equivalent magnetizing inductance of primary
T_r = ideal transformer of primary-to-secondary ratio of $1/r$
L_s = secondary leakage inductance
C_s = total shunt and distributed capacitance of transformer secondary and modulation inductor
C_c = coupling capacitance between transformer and modulation inductor
L_L = modulation inductor (shunt-feed inductor)
C_L = radio-frequency by-pass capacitor plus capacitance of wiring
R_L = equivalent resistive load of radio-frequency amplifier

If it is assumed that the winding resistances and core losses are negligibly small, that the coefficient of coupling is practically unity, and that any primary-to-secondary capacity effects are negligibly small, then Figure 2 will be recognized as the general equivalent circuit, where all circuit values such as shunt-feed reactor, load, and so forth, are referred to the primary. The circuit elements in Figure 2 are as follows:

L_1 = total transformer leakage inductance referred to primary = $L_p + L_s/r^2$
L_2 = primary exciting inductance = L_e
L_3 = inductance of shunt-feed reactor referred to primary = L_L/r^2
C_1 = total shunt capacitance of load, shunt-feed reactor, and transformer = $r^2(C_S + C_L)$
C_2 = capacitance of coupling capacitor referred to primary = r^2C_c
C_3 = total shunt capacitance of transformer primary and wiring = C_p
R_1 = equivalent resistance load referred to primary = R_L/r^2

Since the analysis is to apply to transformers having broad-band characteristics, the equivalent circuit can be simplified by dividing the frequency range into three sections—low, medium, and high frequency. The medium-frequency region is the band over which the reactive elements have negligible effect and so the simple circuit of Figure 3*A* holds true. At high frequencies the effect of the series inductances and shunt capacitances are all that need to be considered; hence the equivalent circuit at the high-frequency end of the passband becomes that of Figure 3*B*. At low frequencies only the shunt inductances and series capacitances need to be considered; hence the equivalent circuit of Figure 3*C* is valid. These equivalent circuits now represent the transformer and circuit as relatively simple networks made up of elements of resistors, inductors, and capacitors.

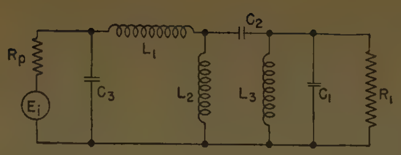

Figure 2 (above). General equivalent circuit of modulation system reduced to unity ratio and referred to the transformer primary

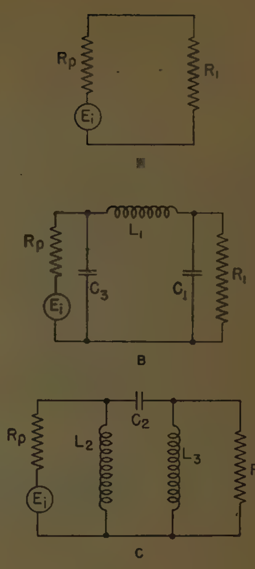

Figure 3 (right). Simplified equivalent circuits for limited frequency ranges

In order to obtain a simple terminology for expressing the interrelationship of these elements, it seemed desirable to avoid the use of such frequency-dependent factors as *Q* (quality factor) and *D* (dissipation factor). This can be done if the reactive elements *L* and *C* of the networks are treated as elements of an artificial line of characteristic impedance Z_0 defined by the expression $Z_0 = \sqrt{L/C}$. This term is commonly used in connection with pulse-transformer design;[4] so it seems reasonable to apply it to broad-band transformer design. If the circuit of Figure 3*B* is treated as an artificial line, it will have a characteristic impedance Z_{01} equal to $\sqrt{L_1/C_1}$. Figure 3*C* also can be considered as an artificial line of characteristic impedance Z_{02} equal to $\sqrt{L_3/C_2}$. These circuit constants can be conveniently related to frequency by the equation for electrical resonance. Thus, for the high-frequency circuit, $2\pi f_{01} = \omega_{01} = 1/\sqrt{L_1C_1}$, and for the low-frequency circuit, $2\pi f_{02} = \omega_{02} = 1/\sqrt{L_3C_2}$. These terms are applicable even if the capacitor C_3 and inductor L_2 are of such values that they can be neglected.

This terminology for describing the equivalent circuits of the transformer, their relations to each other and to frequency, is readily understood by both electronic-circuit designers and transformer designers. It employs nothing which is unfamiliar to the circuit designers since it avoids such terms as magnetizing reactance and leakage reactance. The term characteristic impedance may be new to some transformer designers. However, its definition is relatively simple and experience indicates that transformer designers accept this term more readily than they accept the terms *Q* and *D*.

GENERALIZED RESPONSE CURVES

Having established a terminology, the equivalent circuits representing several types of coupling transformers at the high and low regions of the bandpass were analyzed relative to such important frequency response characteristics as output voltage, output phase, and input impedance. Because of space limitations, the results of only a few of those analyzed are shown here as examples of this phase of the project.

Perhaps the most important characteristic of the combined amplifier and transformer is the manner in which the ratio of the output voltage to the input voltage varies with fre-

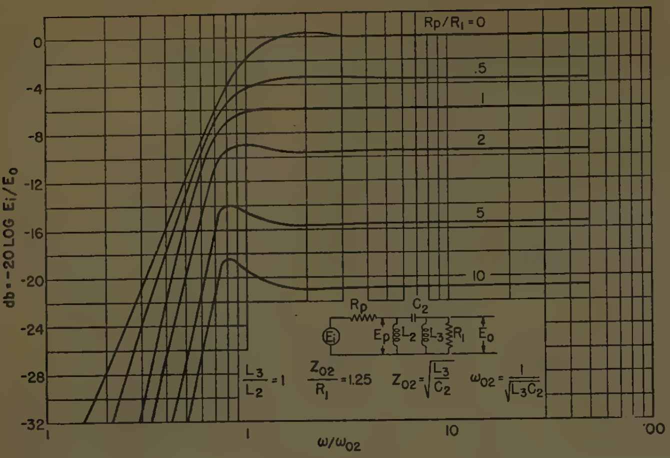

Figure 4. **Generalized frequency-response characteristic. Output voltage at low frequencies**

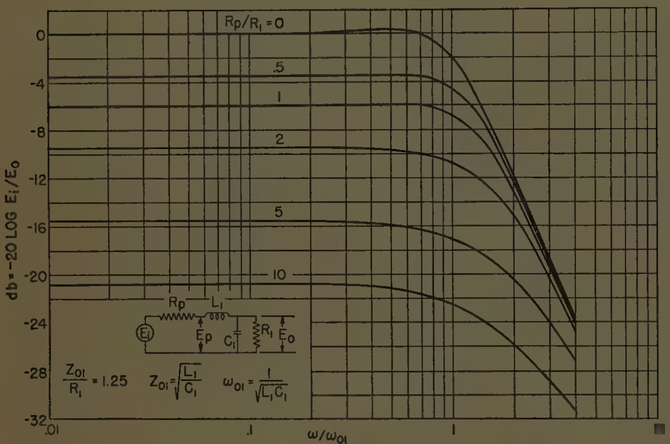

Figure 5. **Generalized frequency-response characteristic. Output voltage at high frequencies**

quency. In many instances the allowable variation of this ratio over the useful portion of the passband must be held to a very constant value. For example, it is not uncommon in audio-amplifier circuits to require that this voltage ratio be held constant within ±1/2 decibel (±6 per cent) from 20 cycles to 20,000 cycles. Figures 4 and 5 illustrate the theoretical generalized frequency-response curves of this voltage ratio for several ratios of tube plate resistance to equivalent load resistance. Note that the frequency parameter is expressed as a ratio so as to be applicable to any frequency range that may be determined by the equivalent-circuit constants. The particular equivalent circuit analyzed to obtain each set of curves is shown schematically in each illustration.

Another important characteristic is the impedance presented to the tube by the combined transformer, network, and load. Large dips in impedance within the normal operating range must be avoided since they tend to increase the distortion in the associated amplifier tubes.[3] Study showed that a ratio of $Z_0/R_1 = 1.25$ provides the best compromise between the impedance characteristic and the output voltage characteristic.

Except when a feedback loop includes the transformer, the phase angle of the output voltage with respect to the input voltage as a function of frequency is of little importance in many audio amplifiers. This phase angle is important in video-amplifier circuits for radar and television. Figure 6 and Figure 7 show frequency response curves of this characteristic.

SPECIFICATIONS REQUIRED

In order to design a transformer using these theoretical curves, the circuit designer must provide the transformer designer with certain specifications which adequately describe the circuit in which the transformer is to be used and the over-all performance required. An outline of the essential specifications follows:

I. Circuit Characteristics
  A. Load
    1. Equivalent load resistance.
    2. Total value of shunt capacitances.
    3. Required maximum audio power into load.
    4. Component of direct current into load.
  B. Power Source
    1. Characteristic impedance for a line or cable.
    2. For an amplifier—single-ended; push-pull, class *A* or class *B*.
      (*a*). Minimum average plate resistance (this should include the effect of feedback in modifying the actual plate resistance).
      (*b*). Plate current at zero signal and maximum signal; maximum unbalance if push-pull.
      (*c*). Peak plate current.
      (*d*). D-c plate-supply voltage.
      (*e*). Peak-to-peak plate voltage swing.
II. Transformer characteristics
  A. Secondary
    1. Maximum allowable winding resistance.
    2. D-c component of voltage to ground.
    3. Peak-to-peak voltage swing or rms value of alternating-voltage component.
  B. Primary
    1. Maximum allowable winding resistance.
    2. Normal value of impedance presented to power source with load connected.
  C. Minimum Allowable Efficiency
III. Over-all Performance of Transformer and Circuit
  A. Frequency-Response Characteristics
    1. Load voltage.
      (*a*). Amplitude versus frequency.
      (*b*). Phase versus frequency when required.
    2. Primary impedance (minimum allowable within operating range, as per cent of normal).
    3. Signal amplitude (maximum required input signal in per cent of normal as a function of frequency).
  B. Harmonic distortion (maximum allowable attributable to the transformer, excluding that caused by impedance effects).

OUTLINE OF DESIGN PROCEDURE

A design procedure is fairly straightforward when based upon these generalized response curves and a suitable set of specifications covering the transformer and circuit performance requirements. First, the required transformer turns ratio $1/r$ of the primary to the secondary is calculated from the specified transformer ratings and used to determine an equivalent value for the resistive component of the load as reflected to the primary. Then the ratio of this reflected load resistance to the average effective plate resistance of the amplifier tube, as given by the specifications, provides the necessary information to select the particular generalized frequency-response curve which should be used at each end of the passband. These two curves are then employed to determine values for the magnetizing inductance, the total leakage inductance, and the allowable secondary shunt capacitance, in the following manner.

For illustrating this procedure, assume the transformer is coupled to the load through a shunt-feed inductor and coupling capacitor. Their equivalent primary values, as well as the transformer magnetizing inductance, can be determined from Figure 4 and the specified low-frequency response characteristic. For example, suppose the reflected load resistance R_1 is 10,000 ohms, the effective plate resistance R_p is 20,000 ohms, and the output voltage must be no more than one decibel down at 50 cycles. The curve for the ratio of $R_p/R_1 = 2$ of Figure 4 is then the one to use. The output voltage for this curve is down one decibel from the mid-frequency value of -9.5 decibels at ω/ω_{02} of 0.72, from which $\omega_{02} = 2\pi \times 50/0.72 = 437$. Since these curves are for $Z_0/R = 1.25$, then $Z_{02} = 12{,}500$. The expressions $Z_{02} = \sqrt{L_3/C_2}$ and $\omega_{02} = 1/\sqrt{L_3C_2}$ can be combined to give the expressions $L_3 = Z_{02}/\omega_{02}$ and $C_2 = 1/Z_{02}\,\omega_{02}$; $L_3 = 12{,}500/437 = 28.6$ henrys is therefore the required reflected value for the shunt-feed inductor. It is desirable that the transformer-primary magnetizing inductance be equal to this same value. The required shunt-feed choke is then $r^2 \times 28.6$ henrys. Also, $C_2 = 1/12{,}500 \times 437 = 0.183$ microfarad is the required reflected value for the coupling capacitor. The required coupling capacitor is then $0.183/r^2$ microfarad. If the primary capacitance is small and so assumed to be negligible, then Figure 5 can be used in a similar manner to determine the total equivalent primary leakage inductance and total allowable secondary and load shunt capacitance. The curve for $R_p/R_1 = 2$ shows the output voltage is down one decibel from the mid-frequency value of -9.5 decibels at ω/ω_{01} of 0.88. If this point is assumed to be specified as the 10-kc point in the specified over-all frequency response characteristic, then $\omega_{01} = 2\pi \times 10{,}000/0.88 = 7.14 \times 10^4$. Hence, the total equivalent primary leakage inductance L_1 should be $12{,}500/7.14 \times 10^4 = 0.175$ henry and the total allowable reflected secondary and load shunt capacitance C_1 should be 0.00112 microfarad. If the specifications call for operating with a shunt capacitance across the load of C_L microfarads, then the total shunt and distributed capacitance C_s allowed for the transformer secondary and shunt-feed inductor will be found by the use of the expression $C_s = C_1/r^2 - C_L$ microfarads.

All of the transformer design constants which affect the frequency-response characteristic have now been determined. From here on the design follows the conventional procedure. The problem becomes one of designing a transformer which will have these constants and which will have sufficient core area and copper cross section to handle the power level as specified for certain frequency ranges within the passband.

HARMONIC DISTORTION ATTRIBUTABLE TO TRANSFORMER

Circuit designers must design systems with harmonic distortions below specified maximum values. The transformer, as a component of the system, must be so designed as to contribute only a fraction of the allowable over-all distortion.

It has been recognized for some time in class-*B* push-pull amplifiers[5] that the leakage inductance between the two halves of the primary winding is a source of distortion in the high-frequency portion of the passband. However, of the only two references found, one[5] assumed linear transfer characteristics for the tubes; hence the theoretical analysis given could not be relied upon for numerical results for a practical amplifier. The other[3] stated that perceptible nicks in the output voltage wave would occur if the ratio of primary-to-primary leakage reactance to average triode plate resistance is four or more. This sort of information is inadequate since modern amplifiers often have tetrodes or pentodes in the output stage and their plate resistance is usually very high. Also, many amplifiers now employ inverse voltage feedback to keep the amplifier distortion low and ten decibels of this type of feedback reduce the apparent

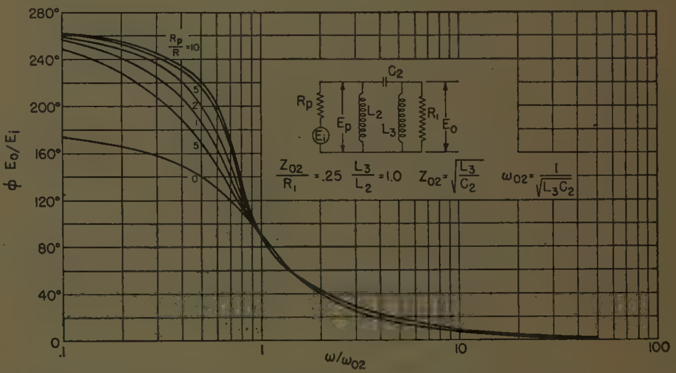

Figure 6. Generalized frequency-response characteristic. Output phase at low frequencies

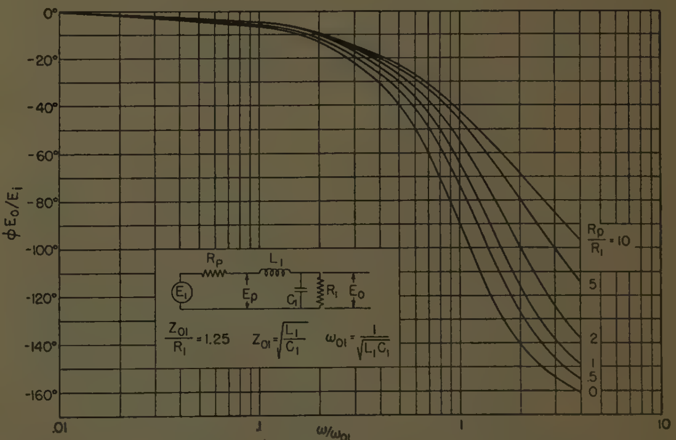

Figure 7. Generalized frequency-response characteristic. Output phase at high frequencies

plate resistance to a relatively low value.[6] Reduction of this leakage inductance to very low values usually requires complex interleaving of the windings. This is not only expensive but may also introduce undesirable capacity effects between winding sections. It is therefore advantageous to be able to determine with reasonable accuracy a value for this leakage inductance which will keep the distortion caused by it below a specified value.

Since the analytical solution of this problem was complicated by nonlinear circuit elements, it was solved experimentally. A transformer was constructed with several windings of equal turns so that the leakage inductance between halves of the primary as well as that between half-primary and secondary could be varied by changing the winding arrangements. Capacity effects were minimized by operating both primary and secondary at low levels of impedance. The apparent plate resistance of the class-*B* push-pull amplifier used for these tests was made very low by operating tubes in parallel and by employing a large amount of inverse voltage feedback from the plates. This feedback also reduced the amplifier harmonic distortion to a relatively small value.

The measured values of the leakage inductances for various connections of this test transformer cover a fair range of values. The leakage inductance between one-half primaries had values from 5.3 millihenrys to 79 millihenrys. The leakage inductance between one-half primary and secondary had values from 11.6 millihenrys to 38 millihenrys. However, when the peak values of distortion as measured for each connection were plotted against the corresponding inductance ratios, they produced curve *A* of Figure 8. Deviation of any test point from this curve was well within the limits of accuracy of instruments available for making harmonic distortion measurements. It therefore seems reasonable to relate this type of distortion to the transformer leakage inductance ratio indicated in Figure 8.

It is frequently assumed that harmonic distortions of these low values can be added and subtracted arithmetically. If the residual distortion is subtracted, then curve *B* of Figure 8 indicates the amount of harmonic distortion which transformers of various values of leakage-inductance ratios will contribute to the circuit. These distortion values apply only to amplifiers with plate feedback. This probably represents the case most susceptible to this type of distortion; so these distortion values are greater than those introduced by a given transformer when operating from class-*B* push-pull amplifiers employing triodes, tetrodes, or pentodes without inverse voltage feedback from the plates.

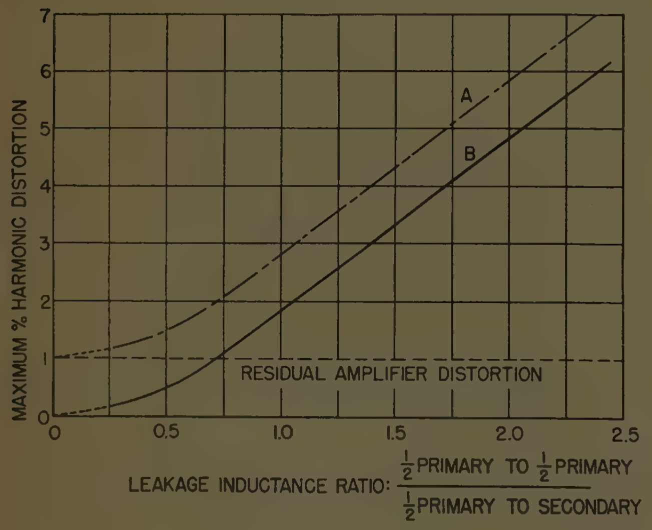

Figure 8. Maximum per cent harmonic distortion at high frequencies as affected by the leakage inductance ratios. (A). Total distortion. (B). Distortion attributable to the transformer

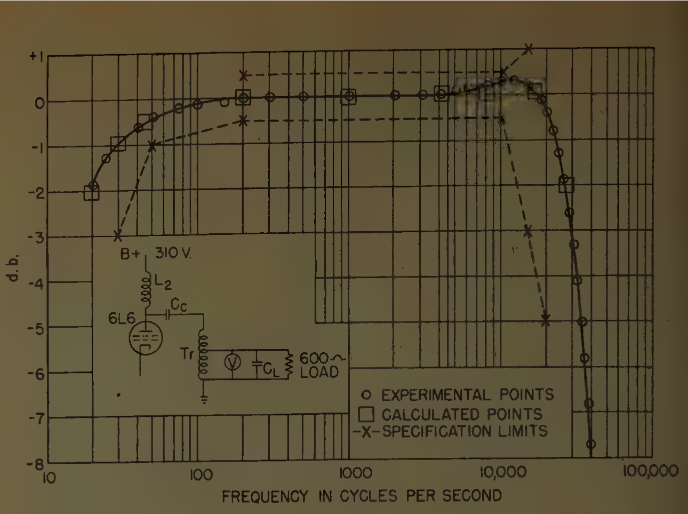

Figure 9. Over-all amplifier frequency response characteristic. Variation of ratio of input voltage to output voltage as measured and as predicted by equivalent circuit analysis

Another source of distortion which the transformer may contribute becomes evident at the low end of the passband. This distortion is caused by the harmonic content in the magnetizing current required by the transformer core. Methods of calculating such distortions have been suggested,[7,8] although they are rather laborious.

APPLICATION RESULTS

A series of some 30 generalized frequency-response curves similar to those of Figures 4 through 7 were prepared for the use of designing engineers of the General Electric Company. These were based upon the theoretical analysis of several equivalent circuits and ratio of parameters.

Before turning this information over to the designing engineers, it was deemed advisable to provide some evidence that the information could be used as a basis for designing transformers which would perform as predicted by the theoretical analysis of the equivalent circuits. As a test case, the Electronics Department of the General Electric Company furnished performance specifications for a 3-watt tube-to-line output transformer needed for frequency-modulation studio equipment. This was chosen as they had yet to obtain a satisfactory unit after testing a series of seven successive designs of developmental samples. Figure 9 shows the frequency response of the output voltage of the first design made with the aid of the theoretical curves. Several points from the theoretical curves are included to indicate the close agreement between the theoretical curves and that obtained by test of this sample unit in the circuit.

After such good results were obtained on this first design, the information and data based upon this terminology were released to the transformer and electronics-circuit designing engineers. The suggested terminology was readily accepted by both groups. A format of the specification sheets for audio transformers was modified by the electronics engineers to permit the use of this new approach to the problem. It then became relatively easy for the transformer designers to use the generalized response curves to convert these specifications into design constants for the required transformer. Transformer designers with no previous experience in audio-transformer design are now able to turn out designs which yield a high percentage of satisfactory first models.

Both groups have benefited through the use of these design data. The transformer designers now receive specifications which are complete and which accurately describe the needs of the circuit designers. First developmental models of small units usually perform satisfactorily in the circuit, thus materially shortening the time the circuit designer must spend upon circuit development and testing. The size and weight of large modulation transformers have been reduced. In some cases this size reduction has improved the high-frequency characteristic to such an extent that satisfactory performance is obtained without the use of compensating and equalizing networks.

Although the examples of this paper have been based upon audio transformers, the curves, data, and design procedures described are generally applicable to video transformers and other broad-band transformers. Circuit designers are continually asking for broad-band transformers of unusual characteristics which may specify operation in a band of frequencies lying within the range of a few cycles to several hundred megacycles. The time required to design and develop transformers to meet their needs is materially shortened through application of these techniques in the engineering of the new design.

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Electrical Essays

Motionally Induced Electromotive Force—Part I

E and B in Moving Matter

Jack, the physicist, has agreed to give a lecture to Alter Ego and his friends, explaining how electric motors work. Of course, Alter Ego is a most attentive listener. Jack has just described the slide-wire experiment of Figure 1.

Jack: "Now we have seen that the force **F** exerted by the electric and magnetic fields on a moving particle or small material body, bearing a charge q, and moving with velocity **v**, is given by the famous Lorentz formula

$$\mathbf{F}=q\left(\mathbf{E}+\frac{1}{c}[\mathbf{v}\times\mathbf{B}]\right) \qquad (1)$$

Apply this relation to the electrons in the metal crossbar of Figure 1. We see that each electron, since it has to move along with the crossbar with velocity **v**, will have acting on it not only the force arising from any electric field **E**, which may be present, but also the force arising from its motion in the magnetic field, so that the total force on it will be

$$\mathbf{F}_e=e\left(\mathbf{E}+\frac{1}{c}[\mathbf{v}\times\mathbf{B}]\right) \qquad (2)$$

where e is the charge on the electron.

"This force, F_e, ..."

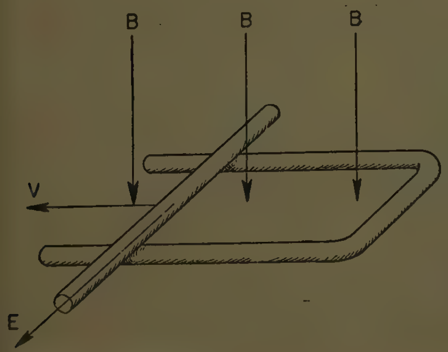

Figure 1. The slide-wire experiment

Alter Ego, interrupting: "May I ask a question? What is the shape of the holes these electrons move in?"

Jack: "Why, Alter Ego, what do you mean?"

Alter Ego: "Well, these electrons moving around in the metal have to have some empty space to move around in, in between the atoms, or how could they move? Now, what I want to know is, what is the shape of that empty space or hole that the electron moves in. I read somewhere (*EE, Sep'50, pp 791–2*) that the force on a small charged body which has been placed in a hole in a body lying in an electric and magnetic field is different depending on the shape of the hole.

"For example, if the hole for the electron in the crossbar is a lozenge-shaped hole with its faces perpendicular to the magnetic field, then inside that lozenge-shaped hole the electric and magnetic fields for the directions we use will be **E** and **B**, and we would then have for the force on the electron

$$\mathbf{F}=e\left(\mathbf{E}+\frac{1}{c}[\mathbf{v}\times\mathbf{B}]\right) \tag{3}$$

corresponding to your equation 2.

"However, if the faces of the lozenge-shaped hole are perpendicular to the electric field, then the field components in the hole would be **D** and **H**, and we would have

$$\mathbf{F}=e\left(\mathbf{D}+\frac{1}{c}[\mathbf{v}\times\mathbf{H}]\right) \tag{4}$$

and if the faces of the hole are perpendicular to v, then we have

$$\mathbf{F}=e\left(\mathbf{E}+\frac{1}{c}[\mathbf{v}\times\mathbf{H}]\right) \tag{5}$$

"If the hole isn't lozenge-shaped at all, but spherical then we would have

$$\mathbf{F}=e\left(\frac{3\epsilon}{2\epsilon+1}\mathbf{E}+\frac{3}{2\mu+1}\frac{1}{c}[\mathbf{v}\times\mathbf{B}]\right) \tag{6}$$

where ϵ and μ are the dielectric constant and permeability of the crossbar material. None of these equations 4, 5, and 6 agree with your equation 1.

"So, Dr. Jack, please tell me what is the shape of the hole the electron moves in, since that will affect the force on the electron."

Jack: "You do ask the darndest questions, Alter Ego. I don't know what the shape of the holes the electrons move in is.

"Lorentz himself worked on the electron theory of matter, where all the electrical and magnetic properties of bodies were accounted for by small charged particles, the electrons and ions producing very intense local electric fields by their charge, and very intense local magnetic fields by their motion, these intense local fields, for any particular point fixed in space, also varying violently in time. Now Lorentz showed that if you take the average of all these local electric fields over a region of space embracing many of these electrons and ions, and over a time interval embracing many fluctuations in their position, then you get the **E** of Maxwell theory. But if you average all the local magnetic fields over the same space region and time interval, you get the **B** of Maxwell theory. That is why we write the force on the electron as shown in equation 2."

$$\mathbf{F}=e\left(\mathbf{E}+\frac{1}{c}[\mathbf{v}\times\mathbf{B}]\right) \tag{2}$$

(*To be Continued*)

Did Jack answer Alter Ego's question properly?

J. SLEPIAN (F '27)
(Westinghouse Research Laboratories, East Pittsburgh, Pa.)

Switching Gravity On and Off

A physicist, studying the electric arc at atmospheric pressure, found that the heat loss from the arc was largely due to convection currents in the air around the arc. These convection currents were, of course, due to the lessened density of the heated air in the gravitational field normally found at the laboratory work bench.

Wishing to eliminate these convection currents, the scientist proceeded to construct means whereby the gravitational field could be turned on and off and its influence on the arc observed.

How did the scientist accomplish this?

J. SLEPIAN (F '27)
(Westinghouse Research Laboratories, East Pittsburgh, Pa.)

Answers to Previous Essays

Surge Impedance? The following is the author's answer to his previously published essay (*EE, Oct '50, p 925*).

It cannot be concluded that the resistance R which the engineer connected across the output terminals of the black box he used to represent a long "loss-less" transmission line is equal to the surge impedance of the line. Had the engineer been investigating a line which was a multiple of a half-wave length, he would have found the magnitudes of the receiving- and sending-end voltages and currents to be equal for any value of R which has been connected to the output terminals.

For a loss-less line the familiar hyperbolic equations can be changed into trigonometric form using the following identities

$$\sinh jm\beta=j\sin m\beta$$

$$\cosh jm\beta=\cos m\beta$$

The long-line equations then become

$$E_s=E_r\cos m\beta+jI_rR_o\sin m\beta$$

$$I_s=I_r\cos m\beta+j\frac{E_r}{R_o}\sin m\beta$$

where

$$Ro=\sqrt{\frac{x}{b}}=\text{surge impedance}$$

$$\beta=\sqrt{xb}$$

x=reactance per mile
b=susceptance per mile
m=miles of line

If the line is terminated in its surge impedance, then

$$I_r=\frac{E_r}{R_o}$$

$$E_s=E_rl\angle\phi$$

$$I_s=I_rl\angle\phi$$

where

$$\phi=\tan^{-1}\frac{\sin m\beta}{\cos m\beta}$$

If the line is a half-wave length long or a multiple thereof

$$m\beta = n\pi$$

$$E_s = E_r\ (-1)^n$$

$$I_s = I_r\ (-1)^n$$

$$A = D = (-1)^n$$

$$B = C = 0$$

where n is an integer expressing the length of line in half-wave lengths.

The engineer either directly connected the respective sending- and receiving-end terminals or cross-connected them, depending on whether n was even or odd, and so it cannot be concluded from measurements made at the terminals of the black box whether R is the surge impedance of the line under investigation.

J. H. DRAKE (A '47)
(Southern California Edison Company, Los Angeles, Calif.)

Equivalent Networks. The following is the author's answer to his previously published essay (*EE, Oct '50, pp 924–5*).

With reference to terminal 1 of the Steinmetz network illustrated in the essay, either terminal 3 or terminal 4 may be selected as the output reference terminal. Depending upon the selection of the output terminal, a set of circuit constants may be found in Table I.

Table I

	Terminal 3	Terminal 4
General circuit constants	$A = 0$	$A' = 0$
	$B = jx$	$B' = -jx$
	$C = jl/x$	$C' = -jl/x$
	$D = 0$	$D' = 0$
Impedance network	$Z_{11} = 0$	$Z_{11}' = 0$
	$Z_{12} = -jx$	$Z_{12}' = jx$
	$Z_{22} = 0$	$Z_{22}' = 0$
Admittance network	$Y_{11} = 0$	$Y_{11}' = 0$
	$Y_{12} = jl/x$	$Y_{12}' = -jl/x$
	$Y_{22} = 0$	$Y_{22}' = 0$
Equivalent π	$Y_s = jl/x$	$Y_s' = -jl/x$
	$Z = jx$	$Z' = -jx$
	$Y_r = jl/x$	$Y_r' = -jl/x$
Equivalent T	$Z_s = jx$	$Z_s' = -jx$
	$Y = jl/x$	$Y' = -jl/x$
	$Z_r = jx$	$Z_r' = -jx$

The two sets of constants for an equivalent π network verify the first statement that the Steinmetz network with one element short-circuited is its own equivalent.

The two sets of constants for an equivalent T network verify the second statement that the Steinmetz network with one element removed is its own equivalent. The remaining single element becomes a shunt admittance in the middle of the network and the remaining two like elements are placed in series on each side of this admittance.

A. A. KRONEBERG (F '48)
(Southern California Edison Company, Los Angeles, Calif.)

New General Electric Measurements Laboratory

This is an exterior view of the Measurements Laboratory of the General Electric Company's Meter and Instrument Divisions at Lynn, Mass. The 5-story brick, steel, and concrete building houses complete facilities for applied research, product development and design in the field of measurements. The new laboratory will be staffed by engineering specialists in magnetism, electricity, chemistry, metallurgy, sound, heat, light, and color. The building contains 142,000 square feet of floor space, the major portion of which is occupied by the laboratory and associated engineering groups, the remainder by administrative staffs of the General Electric Meter and Instrument Divisions. Electric power comes from a power distribution center in the basement. This service offers direct current at 125 volts and alternating current at 240 volts 3-phase and 208/120 volts single-phase

INSTITUTE ACTIVITIES

Technical Committees to Offer Extensive Program at 1951 Winter General Meeting

The Winter General Meeting will again be held at the Hotel Statler, New York, N. Y., during the week of January 22–26, 1951; the hotel will be the center of all meeting activities. This change from the Engineering Societies Building has made it possible to schedule as many as eight technical sessions in one period. Last year this resulted in one of our largest meetings, with a total registration of 3,213 and with 57 technical sessions scheduled. It is expected that the meeting this year will exceed these previous attendance figures by a substantial margin.

The technical committees have shown a keen interest in this meeting. A group of papers will be offered on the subject of Extra-High Voltage Lines in the range of 265 to 500 kv, giving the results of field studies of corona and radio influence, and on the Economics of High-Voltage Transmission with a presentation of some of the characteristics of the highest voltage transmission lines so far planned or built in this country. A session also is being organized on the general subject of Power Capacitor Experience in the Field, and one is being planned which will have as its main topic some interesting information on modern aspects of switching for telegraph communications.

ENTERTAINMENT

The highlights of the evening entertainment program include a smoker at the Hotel Commodore on Tuesday, January 23, and the very popular dinner-dance, to be held Thursday, January 25, at 7:30 p. m. in the main ballroom of the Hotel Statler. Formal dress is requested. An innovation begun several years ago will be continued: dinner tables will not be placed on the dance floor, so each group will be able to remain at its original tables. Reservations may be made with the Dinner-Dance Committee, AIEE Headquarters, 33 West 39th Street, New York 18, N. Y. Each table will seat a group of ten persons.

THEATER TICKETS

It is expected that tickets will be available for various Broadway shows, and members wishing tickets should write AIEE headquarters stating the name of the show, the number of tickets, and the date desired. Every effort will be made to fill requests for all performances for which tickets are obtainable.

LADIES' PROGRAM

The Ladies' Entertainment Committee, under the chairmanship of Mrs. R. F. Brower, is planning an interesting and varied program. Tentative plans under consideration include registration and tea at the Statler on Monday, January 22, from 3:30 to 5:30 p. m.; sight-seeing trips around New York, including, if possible, a visit to the new headquarters of the United Nations; luncheon and fashion show; and possibly a dinner with entertainment the night of the smoker. Theater, radio, and television broadcast tickets also will be available. More complete information will be published in the December issue.

HOTEL RESERVATIONS

Blocks of rooms have been set aside at the Hotel Statler (meeting headquarters) and near-by hotels for members attending. Requests for reservations should be sent early directly to the hotel of choice, and to only one hotel. A copy of the request

Hotel Statler, New York City, headquarters of the Winter General Meeting. The Statler is directly opposite Pennsylvania Station, making it convenient for out-of-town members who use the Pennsylvania Railroad

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Future AIEE Meetings

Conference on Electrical Engineering in the Machine Tool Industry
Sheraton Hotel, Worcester, Mass.
November 14–16, 1950

Conference on Electron Tubes for Computers
Chalfonte-Haddon Hall Hotel, Atlantic City, N. J.
December 11–12, 1950

Conference on High-Frequency Measurements
Hotel Statler, Washington, D. C.
January 10–12, 1951

Winter General Meeting
Hotel Statler, New York, N. Y.
January 22–26, 1951
(*Final date for submitting papers—closed*)

Southern District Meeting
Miami, Fla.
April 11–13, 1951
(*Final date for submitting papers—January 11*)

North Eastern District Meeting
Syracuse, N. Y.
May 2–4, 1951
(*Final date for submitting papers—February 1*)

Great Lakes District Meeting
Madison, Wis.
May 17–19, 1951
(*Final date for submitting papers—February 16*)

Summer General Meeting
Royal York Hotel, Toronto, Ontario, Canada
June 25–29, 1951
(*Final date for submitting papers—March 27*)

Pacific General Meeting
Portland, Oreg.
August 20–23, 1951
(*Final date for submitting papers—May 21*)

Fall General Meeting
Hotel Cleveland, Cleveland, Ohio
October 22–26, 1951
(*Final date for submitting papers—July 31*)

An informal technical conference on New Electronic Devices and Applications is being planned for the Winter General Meeting. Papers or suggested subjects for consideration for this session are desired. No manuscript need be submitted, a title and short abstract only being required prior to November 10.

Please send suggestions to Edward C. Day, Secretary, Technical Program Committee, AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

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should be sent to Mr. C. N. Metcalf, Chairman, Hotel Accommodations Committee, in care of Consolidated Edison Company of New York, Inc., Room 1250-S, 4 Irving Place, New York 3, N. Y. A second and third choice should be indicated on this copy. If requested accommodations are not available, the Hotel Accommodations Committee will arrange for transfer of the reservation to one of the other hotels desired.

Hotel rooms have been reserved at the following:

Hotel Statler (meeting headquarters)
7th Avenue, 32d to 33d Streets

Single room with bath	$ 5.00 to	$ 8.50
Double room, double bed	7.50 to	10.50
Double room, twin beds	9.00 to	14.00
Parlor suites	19.00 to	33.00

Hotel McAlpin, Broadway and 34th Street

Single room and bath	4.50 to	8.50
Double room, double bed	7.00 to	10.50
Double room, twin beds	8.50 to	11.00
Suites	14.00 to	15.00

Hotel Governor Clinton, 7th Avenue at 31st Street

Single room with bath	$ 4.50 to	$ 7.00
Double room, double bed	7.00 to	10.00
Double room, twin beds	8.50 to	10.00

Hotel New Yorker, 34th Street at 8th Avenue

Note: Reservations for arrival January 20th or 21st ONLY. Write to D. W. Carlton, Director of Sales.

Single room, tub and shower	4.50 to	8.00
Double room, double bed	7.50 to	12.50
Double room, twin beds	8.50 to	12.50
Suite accommodations	14.00 to	25.00

Hotel Martinique, Broadway and 32d Street

Single room with bath	6.00 to	9.00
Double room, double bed	6.00 to	10.00
Double room, twin beds	6.50 to	10.00
Two-room suites	10.00 to	18.00

Hotel Commodore, 42d Street at Lexington Avenue

Single room with bath	6.00 to	9.00
Double room, twin beds, bath	10.50 to	12.50

WINTER GENERAL MEETING COMMITTEE

The members of the 1951 Winter General Meeting Committee are G. J. Lowell, *Chairman;* C. T. Hatcher, *Vice-Chairman;* J. J. Anderson, *Secretary;* W. J. Barrett, *Budget Co-ordinator;* C. S. Purnell, *Vice-President, District 3, AIEE;* C. H. Willis, *Technical Program;* J. D. Tebo, D. W. Taylor, D. T. Braymer, *General Session;* N. S. Hibshman, *Medals;* G. T. Minasian, J. B. Harris, Jr., *Publicity;* C. N. Metcalf, *Hotel Accommodations;* E. R. Thomas, *Registration;* D. M. Quick, *Smoker;* Mrs. R. F. Brower, *Ladies' Entertainment;* E. S. Banghart, *Dinner-Dance;* F. P. Josslon, *Inspection Trips;* J. B. Paszkowski, *Theater-Radio.*

Middle Eastern District Holds Successful Meeting in Baltimore

The Maryland Section was host to a 3-day meeting of the Middle Eastern District held in The Lord Baltimore Hotel, Baltimore, Md., October 3–5, 1950. A full program of events was arranged, including 23 sessions in which 98 papers were presented, inspection trips to near-by industries, sports, special entertainment for the ladies, a smoker, and a cabaret dance. An all-day meeting of the Middle Eastern District Executive Committee was held on the day preceding. A total of 972 members, guests, and students attended the meeting.

GENERAL SESSION

The main theme of the General Session was centered on the topic, "Developing Engineers for Industry." Three addresses represented the educational, industrial, and light and power points of view. On the educational side, Dr. W. B. Kouwenhoven gave an address, "Mutual Obligations—the University, the Engineer, Industry, the Engineering Society." Representing the industrial point of view, Past-President Everett S. Lee spoke on "Industry Appraises and Develops the Engineer." From the light and power field, President Titus G. LeClair addressed the meeting on "Is the Engineering Graduate Educated?" President LeClair's address appears on pages 951–2 of this issue; the others will appear later.

Certificates and checks were presented to the winners of the first and second prizes in the District 2 Prize Paper Competition by Vice-President C. G. Veinott. A résumé of the background and experiences of each winner was given by Mr. Veinott, who remarked, in connection with the presentation, that the greatest good comes to him who participates the most and that the same principle applies in relation to prize awards. The awards and names of the winners are announced on page 1034 of this issue.

In accordance with a plan to recognize the work of Section officers, a certificate was presented by Vice-President Veinott to the Cleveland Section for having attained the greatest combined percentage increase in the number of members and attendance over that for the preceding year of any other Section in the Middle Eastern District. The Certificate of Honorable Mention was presented to the Erie Section for having achieved second place in the Section Growth Award two years in succession.

The General Session was opened by J. W. Gore, Chairman of the Maryland Section, who introduced officers and speakers. The presiding officer was Thomas W. Trice.

TECHNICAL SESSIONS

During the remainder of the meeting, technical sessions were held in parallel each morning and afternoon. The subject matter in the technical sessions ranged over the five broad divisions of Institute technical activities, namely, communication, general applications, industry, power, and science and electronics.

Air Transportation I. In the first session held on Air Transportation, Tuesday, October 3, several papers evoked considerable interest. In a paper entitled "Aircraft Electric Motors Need Test Equipment," I. E. Ross of the General Electric Company outlined a program to provide test facilities for evaluating rotating electric equipment not exceeding 100 pounds in weight, an over-all dimension of 30 by 10 by 15 inches, and with d-c or a-c power dissipation of 5 kw, which required two years to complete at an actual expenditure in excess of $160,000. To meet the ever-increasing demand for higher altitude performance, the author described an altitude chamber design, which will provide for light thermal loads an ambient temperature of −45 degrees centigrade at 100,000 feet. The design will dissipate 3 kw plus internal fan and lighting losses at −65 degrees centigrade and 60,000 feet, and a minimum cold temperature at low altitudes of −75 degrees centigrade is predicted. Other components of the test program, such as centrifugal design, mechanical shock, and vibration, were discussed. In the discussion of the test program, some concern was felt as to how the smaller companies might meet the problem. It was hoped that the author would have another paper on the experiences acquired after the new test equipment has been in use.

In another paper, "Tracking Radio Noise on Aircraft," by T. B. Owen of the Hughes Aircraft Company, designs of portable equipment for the injection of a very-high-frequency modulated signal into the ignition harness of an engine and a tuned portable receiver for picking up the signal at points of defect were described. Extension of the injection test method to other electric apparatus and the characteristics of radiation from openings in enclosures were discussed. The advantage of the method is in not having to run the engine for the test and also the method can be used without the aid of a shielded room, which is sometimes prohibitive for the testing of large parts or assemblies (*see page 1019*).

An interesting comparison of electric, hydraulic, and pneumatic actuators for aircraft was presented in a paper by R. C. Treseder and H. M. Geyer of the General Motors Corporation. The analysis was made primarily on a weight basis and rather consistent data on both weight and efficiency of electric generators were obtained by writing to all of the electrical equipment manufacturers. Information obtained from curves of standard aircraft components and from known trends was analyzed to yield bar charts from which the final conclusions were drawn. These charts showed that on the basis of weight required to do a specified actuating job, the pneumatic system was optimum for light work loads and short operating times. For the larger loads, longer operating times, and greater transmission distances, the electric system appeared best. In discussion, the question was raised as to why the diversity factor of the generator had not been taken into consideration, and then compared with a generator several times smaller in size and weight.

The session was presided over by H. F. Rempt, who called for a showing of hands which indicated that the attendance was comprised of approximately 35 accessory or equipment manufacturers, 12 aircraft manufacturers, 19 from the services, 2 or 3 commercial operators, and 2 or 3 educational people or others.

Computing Devices. The subject of one of the opening technical sessions held on October 3 was Computing Devices, presided over by Professor J. G. Brainerd of the University of Pennsylvania. The basic principles of the EDVAC were explained in a paper by S. E. Gluck of the University of Pennsylvania, where this computer was designed and built for the Army Ordnance Department. The EDVAC, which is now at Aberdeen Proving Grounds, Md., has a better memory than ENIAC, employs 3,500 tubes, and is composed of nine units: high-speed and low-speed memory units; a control unit; a reader-recorder; a dispatcher, which controls the entire machine; a shifting and processing system; the computer; the timer containing the pulse generator; and the power-supply unit. The EDVAC stores numbers and takes orders to add, subtract, multiply, and divide, using the binary system of numbers. The memory has a capacity to store 1,024 words.

"The Input-Output System of the EDVAC" was the subject of the next paper presented by R. L. Snyder, Jr., of the Ballistic Research Laboratories, Aberdeen Proving Ground. This system, which uses magnetized wire as the medium of transmission, has been replaced by a system which employs a shift register in the reader-recorder to permit the use of devices having higher speeds of communication. The mechanisms used include a keyboard tape perforator, a high-speed tape recorder, a tape punch, and an automatic typewriter.

H. J. Gray of the University of Pennsylvania presented "Adders and Counters" in the EDVAC. He explained how the binary system can be applied to all types of arithmetical processes and words of instructions.

"Systematization of Tube Surveillance in Large-Scale Computers" was the subject of the paper by Homer Spence of the Aberdeen Proving Ground. He brought out that 90 per cent of the service interruptions of the ENIAC were caused by failure of vacuum tubes, of which there are 18,000 in the computer. In order to gather data for guidance in the design of new equipment and tube-testing procedures, a program of tube surveillance was started at the beginning of 1950. The data, recorded on punched cards, are tube type, use, hours of life, manufacturer, panel location, type of failure, previous service, preheating schedule, date, and test readings. Preliminary results of these tests were presented.

Air Transportation II. The second session on Air Transportation was held on Wednesday, October 4, with D. E. Fritz presiding. The first paper presented, entitled "Circuit Interrupting Phenomena at Altitude," by J. P. Dallas of the Hughes Aircraft Company, made an analytical study of the subject from the point of view of arc immobility and arc reversal in the light of previous investigations. In conclusion, the author suggested that improved performance of aircraft switches and relays incorporating magnetic arc suppression may be achieved by designs concentrating the magnetic field and the arc column and/or shielding the cathode surface from the magnetic field. The simple ring of magnetic material surrounding the cathode contact and shunting the magnetic field away from the contact surface would increase the ratio of relative field densities acting on the arc column and cathode surfaces substantially over simple displacement of the field magnet. In the discussion period, in response to a question in regard to terminal effects, the author advised that the results could be accomplished either horizontally or vertically. To another question, he replied that it was not known why the altitude affects the reversal or mobility of the arc.

The second paper, "A New Circuit Breaker for Aircraft Electric Systems 40 to 125 Amperes, 120 Volts A-C or D-C," by B. S. Beall, III, and P. J. Reifschneider of the General Electric Company, was presented by Mr. Beall. A temperature-compensated thermal element maintained the calibration of the circuit breaker within relatively narrow limits over a wide range of ambient temperatures.

R. L. Harrison of the Hartman Electrical Manufacturing Company spoke on "Aircraft Cutouts and Contactors for Interrupting High Direct Voltages." The author pointed out the design objectives and problems encountered in the development of contactors and cutouts for use in modern d-c aircraft systems where generators of large power capacity are employed.

In the discussion of the Dallas and Beall and Reifschneider papers, the question was raised regarding clearance and moisture getting into the fibre and whether the clearance was sufficient to withstand 40 *g*'s. It was reported by J. P. Dallas that both types of circuit breakers had been tested in the laboratory and that the magnetic circuit breaker performed satisfactorily. In regard to the circuit breaker described by Mr. Beall, Mr. Dallas explained that something had happened to the contactor due to spattering of metal which prevented the contacts from closing. The author replied that in arriving at interrupting ratings at the higher current values, the need had been felt for some further specifications or standards. Another discusser suggested the possibility of some kind of back-up protection.

The last two papers presented in this session were "An Environment-Free 120-Volt D-C High Performance Limit Switch" by T. R. Stuelpnagel of Los Angeles, and "The Design of Reactors for Radio Interference Filters" by L. I. Knudson of General Laboratory Associates, Inc.

Electronic Devices. The first of two sessions on Electronic Devices was held the morning of October 4, and the second in the afternoon. Professor C. V. O. Terwilliger, U. S. Naval Postgraduate School, Annapolis, Md., presided over both sessions. All the authors of the papers presented at these sessions are with the Naval Ordnance Laboratory.

The opening paper, "Instrumentation on Transistors," was given by C. B. Brown, who explained the germanium transistor's functioning as a current amplifier and discussed the current gain between the emitter and collector and how it varied with frequency.

"A Submicrosecond Timer" was presented by R. H. F. Stresan, in which he explained that the heater of a vacuum thermocouple is the heart of the circuit used to measure extremely short time intervals, and this, with two thyratrons with their attendant components, comprise the circuit. The temperature rise of the heater is measured by a peak voltmeter or fluxmeter and times of the order of thousandths of a microsecond can be measured with good linearity.

J. M. Norton's paper, "Underwater Telemetering," brought out that radio waves of frequencies between 1 and 100 megacycles could be propagated through fresh water with but one per cent of the attenuation they experience in going through the same distance of salt water. These findings were made using a signal of several microvolts. His conclusion was that radio waves of these frequencies were practical for fresh underwater instrumentation work.

The first paper of the afternoon session was given by B. D. Gilbert; he described the five wind tunnels at White Oak in which are tested models of missiles. The two larger tunnels with test areas of 40 by 40 centimeters were captured from the Germans, who used them in the development of their *V2* missiles. The principle on which the tunnels operate is suction: a 52-foot diameter sphere is evacuated by six vacuum pumps and then the outside air is admitted through the tunnel by a quick-acting valve. Air velocities of the order of Mach 5 (five times the speed of sound in air) can be obtained for approximately 40 seconds, the air velocity being determined by the size and shape of a nozzle. Air velocities of the order of Mach 10 can be obtained in a smaller tunnel with a 12 by 12 centimeter test area.

"Wind Tunnel Instrumentation at the Naval Ordnance Laboratory" was presented by L. P. Gieseler. He explained the procedure of measuring the drag, roll moment, side force, lift, yaw moment, and pitching moment of a missile model in the Laboratory's wind tunnels using a Kochel external balance. Two sets of readings are necessary, one set with the model installed in the balance and the other with the model removed. The net readings are the forces on the model. Four strain gauges are connected in a bridge circuit, the output being amplified and read on a meter. A cathode-ray oscilloscope null indicator is included.

The instrumentation used with air guns was discussed by G. Stathopoulos. Two air guns, 21 inches and 15 inches in diameter, are arranged side by side and measuring instruments near them can be used with either one, a 6-channel recording cathode-ray oscilloscope being one of the main instruments.

S. J. Raff read a paper entitled "Precision Magnetic Tape Recordings of Low-Frequency Signals." This was a description of the apparatus and procedure for the recording and playback of signals from 0 to 10 cycles at the microvolt level. A carrier of 80 cycles is amplitude-modulated by the low-frequency signals and the recorder is slowed up to 1/28 of its normal speed, as it must run continuously for 24 hours under special conditions of test.

Rotating Machinery II. Among the papers presented in a session on Rotating Machinery held on Wednesday, October 4, considerable nterest was shown in a paper entitled 'Thermalastic Insulation for Turbine Generators" by C. M. Laffoon and G. L. Moses of the Westinghouse Electric Corporation. The application of the new insulation to turbine generators of the conventional half-coil construction was explained by Mr. Moses. The new insulation consists of: 1. mica-taped ground wall employing a synthetic resin bound in mica tape applied in multiple continuous overlapped layers; 2. Fiberglas outside binder tape; and 3. impregnation with a solventless synthetic resin which provides solid yet resilient bonds between the mica flakes comprising the ground wall and fills the interstices to a high degree. The coils are insulated from ground by multiple layers of continuous mica tape. A newly developed mica tape used is bonded with a synthetic resin with excellent electrical properties which contribute to low dielectric loss and high dielectric strength. The tape is applied dry without employing brushing bond between layers, such as was necessary with asphalt-bonded tape. The new insulation was reported to have considerably improved physical and electrical properties as compared with conventional insulation. The insulation power factor is decreased by one-half to two-thirds at operating temperature and rated operating voltage. The power-factor voltage curve is flatter and the value is lower at every point. The dielectric strength per unit thickness is increased at least 20 per cent and the voltage endurance (time to failure at a fixed voltage) is increased by a factor of more than ten times. The substitution of an elastic bond for the bonds used in earlier insulations, such as a rigid brittle bond (shellac) and a plastic semiliquid bond (asphalt), and the inherent ability of the new bond to accommodate itself to the deformation resulting from differential thermal expansion of iron, copper, and insulation with increased physical strength, are believed to be its most significant properties.

In discussing the new insulation, C. E. Kilbourne of the General Electric Company congratulated the authors on their presentation but pointed out that such a new development would take considerable time and experience in service to establish its relative merits. He cited that when the silicone insulations were first advocated, they were most carefully checked from every angle; some time later it developed in service that silicone vapor was not compatible with brushwear. In closing, Mr. Moses drew attention to the fact that the development of the new insulation had been under way in the laboratory for a period of years and he agreed that time must be allowed for the insulation to prove itself in service.

Electric Welding. In a session on Electric Welding held on Wednesday, October 4, with T. B. Jones presiding, five papers were presented which offered a rather varied program. Considerable interest was shown in a research investigation of "D-C Arcs with High-Speed Electrodes" by W. B. Kouwenhoven and T. B. Jones of The Johns Hopkins University; the paper was presented by Bernard H. List. Two methods were employed: one involved the use of sheet steel on a drum of 10-inch diameter in a lathe; the other employed a continuous metal tape six inches wide which was run on pulleys. These methods permitted investigation of anode speeds up to 6,000 feet per minute. The moving anode spots were photographed with high-speed motion pictures at a rate of 3,000 frames per second, which permits the intense energy of the arc to be spread out in time and space; thus a unique method of analyzing the phenomena which have not previously been studied has been worked out and will be continued with other anode materials and other anode speeds.

The rest of the papers presented at this session considered the radio interference aspects of high-frequency stabilized welding transformers, instrumentation for investigating the quality of electric welds, effect of cover characteristics on electrical behavior of electrodes, and an automatic all-position welding head for electrode testing which was accomplished hydraulically.

Land Transportation. A session on land transportation was held in the afternoon of October 4, the opening paper being "Motors and Controls for Diesel Electric Locomotives" by T. L. Weybrew, Westinghouse Electric Corporation. He brought out the fact that last year approximately one-third of the freight and one-half of the passengers were hauled by diesel locomotives. Then the author discussed the no-transition feature of diesels, the load control, full power utilization, and so forth. There has been an increase in horsepower rating of the diesel engines themselves by builders, the result being that the locomotives can haul the same train faster, a slightly heavier train at the same speed, or a still heavier train at a slightly lower speed.

C. B. Risler of the Westinghouse Electric Corporation presented "Electric Drives for Baltimore's New Ore Handling Facilities." He described the electric apparatus and its functioning in the various unloading facilities on Baltimore's docks.

"Railroad Radio," by L. J. Prendergast of the Baltimore and Ohio Railroad Company, was in the nature of a report on the present status and usage of radio in railroad operation. Since the authorization of radio communication in railroading in 1945 by the Federal Communications Commission, 88 railroads now are using radio. One of its greatest uses is found in yard and terminal operations, as here the yard master can be in constant communication with yard crews. The largest installation for train service is on the Erie Railroad, which has equipped its main line from Jersey City, N. J., to Marion, Ohio, 884 miles apart, with 53 fixed stations and 200 radio-equipped locomotives for freight and passenger operation. The author also discussed the use of walkie-talkie sets on freight trains for communicating between locomotive and caboose, and the carrier or inductive type of train communication in which wayside wires are used as a conducting medium and trains are equipped with loop antennas by means of which sufficient energy can be picked up so that communication can be maintained between trains and stations or between the two ends of a train.

"Sealed Ignitron Rectifiers for Urban Transit Power Supply," by D. W. Borst of the General Electric Company, was the final paper of the session. The author discussed the present trend in rectifier substation equipment when the unit ratings are 1,000 kw and less. This trend appears to be toward sealed ignitron rectifiers because of the lower equipment, installation, and operating costs and the greater safety to operators and maintenance personnel.

Insulation. In the session on Insulation held on Thursday, October 5, with R. L. McCoy presiding, three papers were presented. The first paper, "Silicone Fluid Surface Treatment for Insulators Operating in Contaminated Atmospheres" by A. L. Baldock, General Electric Company, R. H. Lee, E. I. du Pont de Nemours and Company, and H. A. Frey, Locke, Inc., recorded results of a joint investigation of the application of silicone fluid to insulators which had been contaminated by a metallic powder with sulphuric acid. The results indicated that treated insulators, when subjected to AIEE standard precipitation tests, had flashover voltages approximately 10 to 20 per cent higher than those of untreated insulators. In mist, treated insulators have flashover voltages from 20 to 92 per cent higher than those of untreated insulators. Treated insulators were very much more easily cleaned by hand rubbing, and there was considerable evidence that the periods between washings could be greatly prolonged by respraying the dirty insulators over the existing dirt film. In the tests, the unwashed units were resprayed with silicone fluid bimonthly and they performed equally as well as those which were periodically washed. Spraying could be accomplished at distances of two to four feet with the ordinary garden variety of sprayers, as the material impinges and spreads over the surfaces of the insulators very readily. Mr. R. H. Lee presented this paper, and in conclusion he pointed out that much more information is needed to determine the performance of insulators treated with silicone fluid under other conditions, such as salt spray, cement dust, and other types of industrial dirt.

The second paper, written by I. F. Freed of the Consolidated Gas Electric Light and Power Company of Baltimore, dealt with the subject of "Live-Line Insulator Washing with a Low-Pressure Water Stream." The results of tests which were made to design a nozzle that would provide the most solid water stream for the greatest distance for washing insulators were reported. An investigation also was made of the effect upon the efficiency of washing the dirty insulators when the washing times, water pressures, orifice diameters, and washing distances were varied. Safe distances were based on the values of let-go currents recorded in the paper on "Electric Shock" by C. F. Dalziel, J. B. Lagen, and J. L. Thurston so that the maximum leakage currents would not exceed eight or nine milliamperes. Added precautions were taken to ground the nozzle to the platform on which the operator stands, operators were required to use rubber gloves, and the washing equipment had to be properly grounded. In conclusion, the author pointed out that scheduled washings of insulators on lines and areas giving trouble would increase their wet flashover values sufficiently to permit them to stay in service for an additional prolonged period of time, and that the hazards of extinguishing pole fires might possibly be eliminated by periodic washings which would increase the wet flashover values and reduce the leakage current to the pole and ground. The tests demonstrated that the low-pressure water-stream method of washing insulators is both practical and economical. In the Baltimore area, the resistance of the water supply is 8,200 ohms per cubic centimeter.

The third paper, "Basic Impulse Insulation Levels and Their Relation to Outdoor Switch and Bus Insulators," was presented by R. L. McCoy of Locke, Inc. In view of the recent study of basic impulse insulation levels (BIL) in the light of modern lightning-arrester performance with the possibility that the BIL in the higher voltages can be materially reduced so far as the internal insulation of transformers and circuit breakers are concerned, the author analyzed the situation in respect to outdoor switch and bus insulators. His analysis considered trends in insulator design, taking into consideration such factors as the increases in surface contamination in many areas, radio interference, and the low-frequency performance of station insulators. In conclusion, he recommended that a concerted effort be made by manufacturers and operators similar to the effort expended in studying and solving the lightning problem; committee work and surveys of contamination severity and relative performance are needed badly. Until the adequacy of present low-frequency withstand values has been determined for presently prevailing atmospheric contamination, and experience obtained where switch and bus insulators and apparatus bushings are used, caution is urged in selecting such insulators on the basis of impulse withstand capabilities alone.

Television. Two sessions on television were held on October 5, with S. C. Miller of the Chesapeake and Potomac Telephone Company as chairman. The opening paper, "UHF Television Receiver Design Problems," was presented by J. M. Miller, Jr., and L. E. Davies of Bendix Radio Division of the Bendix Aviation Corporation. Fundamental problems in receiver design such as noise factor, spurious responses, choice of an intermediate frequency, oscillator radiation, and so forth, were considered and evaluated with respect to an ultra-high-frequency (UHF) television receiver. Antennas and tuning elements for such receivers were discussed. The probable design of a UHF converter to provide UHF reception to owners of very-high-frequency sets was outlined.

The next paper, "Blocking Oscillator Design Considerations in the Television Receiver," was given by A. F. Giordano of Allen B. DuMont Laboratories. The subject was discussed from the viewpoint of the circuit designer and dealt primarily with the vertical-deflection blocking oscillator, although it also could be applied in principle to the horizontal-sweep blocking oscillator.

N. S. Kornetz of the Westinghouse Electric Corporation presented a paper on "Sync Circuit Design for Good Noise Immunity" in which he brought out that automatic frequency control of the horizontal-sweep oscillator is a requirement for good sync stability. This means that instead of having the flyback of each line initiated by the horizontal-sync pulse as received, it is triggered by a pulse from a local stable oscillator which is controlled by the integrated voltage of several synchronizing pulses. Such a circuit is effective in removing random displacement of lines due to the triggering of the horizontal oscillator by thermal noise voltages for signal strengths approaching the maximum usable sensitivity of the receiver. The author described a saw-tooth type to demonstrate the fundamental action of such control circuits.

"Influence of Power System Voltage on Television Receivers" was written by H. E. Campbell and D. R. Samson of the General Electric Company, and read by the latter. He presented the findings of tests made on five television receivers of different makes in which the input voltage was varied over a 20-volt range, and photographs made of the images on the screen every 5 volts. It was found that the size of the pictures varied with the voltage and that the focus falls off with a decrease in voltage. The maximum allowable variation is ±5 volts from the rated voltage.

P. R. Breen of the Allen B. DuMont Laboratories presented "A Building-Block Type Television Transmitter," in which he described a series of television transmitters for the very-high-frequency channels (2–13) based on a building-block principle of furnishing the standard power output steps of 0.5 kw, 5 kw, and 50 kw. This equipment consists of a basic complete transmitter of 0.5-kw rating with amplifier packages which may be added to obtain higher power output.

"Leased Short-Haul Television Channels in Maryland" by W. W. Holloway of the Chesapeake and Potomac Telephone Company of Baltimore described how the various wire channels were installed within the vicinity of Baltimore and the microwave radio links between Baltimore, Washington, and other cities to the north.

Instruments and Measurements. The session on Instruments and Measurements was held in the afternoon of October 5. "Instrumentation for Aircraft Navigation" was the opening paper, presented by W. L. Webb of Bendix Radio Division of Bendix Aviation Corporation. He explained the use and functioning of the various magnetic and electronic instruments in the cockpit of a plane for its navigation on domestic Federal airways.

S. S. Haynes, of Friez Instruments Division of Bendix Aviation Corporation, read a paper on "Automatic Pressure Calibration Equipment." He described the apparatus used to calibrate precision multipoint pressure switches used as components in meteorological radiosondes and the methods of calibration employed.

"An Ultrasonic Method for Measuring Water Velocity" by W. B. Hess, Safe Harbor Water Power Corporation, R. C. Swengel, consultant, and S. K. Waldorf, Pennsylvania Water and Power Company, was the next paper. The method is essentially calculating water velocity from the measured phase angle between the transmitted ultrasonic signal and the signal received after passing through the moving water. The transducers used for the measurement were placed on the opposite walls of a 5 by 9-inch duct and displaced some definite distance along the principal axis of flow. Errors of less than two per cent were obtained. It is believed that this method is more easily applicable to the measurement of water flow in hydroelectric units than those methods now used (*see page 983*).

The final paper of the session was "Electrical Instrumentation in Medical Research" by J. M. Benjamin, Jr., Franklin X-Ray Company, and J. Hale, E. L. Carstensen, and H. E. Tompkins of the University of Pennsylvania. The authors described the program at this university having as its object biological research toward closer collaboration between the physical and biological sciences. There followed a description of the apparatus for measuring body and skin temperatures using both thermistors and thermocouples, and for measuring blood pressure and flow.

ENTERTAINMENT

On Tuesday evening, the smoker was held. An old-time Maryland Oyster Roast was served, followed by boxing matches and wrestling bouts with participants from several of the Boys' Clubs in the vicinity.

On Wednesday evening, an informal cabaret dance was held in the Ballroom of the Lord Baltimore Hotel. The music was rendered by Jack Lederer's Orchestra. Door prizes were given, which were furnished by electrical manufacturers and distributors in the district.

LADIES' ENTERTAINMENT

During the meeting, a suite of Hostess rooms was maintained where hostesses extended a cordial welcome and performed introductions of visitors. Shopping tours and visits to points of interest were arranged. A tour was made through McCormick and Company, House of Spices. On the evening of the stag smoker, a dinner was served in the Caswell Room of the Lord Baltimore Hotel, which was followed by a fashion show sponsored by Hutzler Bros. On the following day, a trip was made by bus to Annapolis, where various historical houses and the Naval Academy were visited, and a reception at the Governor's Mansion attended.

INSPECTION TRIPS

During the meeting, a number of inspection trips were arranged to near-by industries and places of interest. Notwithstanding the restrictions as to proof of citizenship, the trip to the Aberdeen Proving Grounds and The Glenn L. Martin Company proved to be very popular. Trips also were taken to the Bendix Radio Division of the Bendix Aviation Corporation, Locke, Inc., The Riverside Generating Station, and the Electronics Division of Westinghouse Electric Corporation.

COMMITTEES

Members of the District Meeting Committee which made the arrangements are as follows: Thomas E. Marburger, *General Chairman;* G. Russell Page, *Arrangements;* L. G. Smith, *Students;* Paul L. Betz, *Technical Meetings;* Thomas W. Trice, *Special Meetings;* M. C. Albrittain, *Finance;* T. H. Marshall, Jr., *Publicity;* Donald Gunn, *Smoker;* W. C. Wilkinson, *Sports;* Charles Wallace, *Entertainment;* C. R. Durling, *Cabaret Dance;* Eduard Fritz, *Registration;* C. S. Fiske, *Inspection Trips;* Mrs. J. Lawrence Hildebrandt, *Ladies.* Hosts: Maryland Section of AIEE: John W. Gore, *Chairman;* John McGee, *Vice-Chairman;* Ferdinand Hamburger, *Secretary.*

Tentative Program Released for 1950 Machine Tool Industry Conference

The 1950 Technical Conference of the Machine Tools Subcommittee of the AIEE Committee on General Industry Applications will be held at Worcester, Mass., November 14–16, 1950, with headquarters at the Sheraton Hotel.

The conference will include three technical sessions and two plant visitation programs, which include trips to the machine tool plants in the Springfield, Vt., area.

The program is set tentatively as follows:

November 14

8:30 a.m.—Registration

9:00 a.m.—Technical Session

1:30 p.m.—Plant Visitation, Worcester Area

6:30 p.m.—Dinner at Sheraton Hotel. Speaker to be announced

November 15

9:00 a.m.—Technical Session

1:30 p.m.—Technical Session

6:30 p.m.—Leave for Springfield, Vt.

November 16

Plant Visitations in Springfield and Windsor, Vt., area

The list of technical papers is incomplete as yet. Other papers are in preparation. Those scheduled so far are:

The Magnetic Amplifier—What It Is and Where to Use It. *W. D. Cockrell*, General Electric Company

How and Where to Apply Solenoids. *W. P. Patrick*, General Electric Company

A Practical Approach to the Selection of Drive Equipment for Duty Cycle Applications. *Fred D. Snyder*, Westinghouse Electric Corporation

Principles and Problems of Dynamic Balancing. *W. I. Senger*, Gisholt Machine Company

Flux Studies and New Controls for Magnetic Clutches and Brakes. *J. A. Mason*, Warner Electric Clutch and Brake Manufacturing Company

Control Transformers. *J. M. Frank*, Hevi Duty Electric Company

Machine Control Problems. *E. E. Opel*, National Automatic Tool Company. This will be an open forum discussion initiated by Mr. E. E. Opel, assisted during the discussion by other machine tool control experts.

Considerations in Establishing High-Frequency Ratings for Machine Tool Applications. *R. T. Fenn*, Bryant Chucking Grinder Company. Discussion by S. I. Rice and B. F. Hammarstrom, The Heald Machine Company.

Plants to be visited on the afternoon of November 14 are the Norton Company, manufacturers of grinding wheels and grinding machines; The Heald Machine Company, manufacturers of precision grinding and boring machines; and the Whitin Machine Company, makers of textile machinery. Mr. S. I. Rice, Chief Electrical Engineer, The Heald Machine Company, is making arrangements for the inspection trips to these plants.

Those participating in the inspection trips to the machine tool plants of the Springfield, Vt., area will leave Worcester on November 15 at 5:30 p.m. and spend the night at hotels in Springfield. On November 16 inspection trips will be made to Bryant Chucking Grinder Company, Jones and Lamson Machine Company, Cone Automatic Machine Company, and Fellows Gear Shaper Company. Luncheon will be at the Constitution House in Windsor, Vt.

The committee in charge of the Vermont trip consists of William Piper, Chief Electrical Engineer, Jones and Lamson Machine Company; Roger Brown, Chief Electrical Engineer, Cone Automatic Machine Company; and Ray Fenn, Electrical Engineer, Bryant Chucking Grinder Company. The committee will arrange transportation to Springfield and to the plants to be visited, and will arrange accommodations. Train connections out of Vermont also can be made by the committee.

The members of the Machine Tools Electrification Subcommittee conducting the conference are D. R. Percival, *Chairman*, Machinery Electrification, Inc., 98 Union Street, Worcester 8, Mass.; B. T. Anderson, Rockford, Ill.; R. W. Brown, Windsor, Vt.; J. M. Delfs, Schenectady, N. Y.; R. T. Fenn, Springfield, Vt.; L. W. Herchenroeder, East Pittsburgh, Pa.; J. J. Jaeger, West Hartford, Conn.; E. F. Mekelburg, Milwaukee, Wis.; W. J. Piper, Springfield, Vt.; S. I. Rice, Worcester, Mass.; E. J. Rivoira, Cincinnati, Ohio; R. E. Stroppel, Cincinnati, Ohio; and W. B. Wigton, Cincinnati, Ohio.

Assisting the Machine Tool Committee in making arrangements for the Conference are members of the Worcester Section, AIEE: R. E. Pfeif, Chairman of Worcester Section; B. F. Hammarstrom, General Chairman of Co-operating Committee; Warren Howard, Bertil F. Hammarstrom, Publicity Committee; Wilfred G. Coleman, F. P. Dunigan, Jr., Finance Committee; and G. R. Blake, George Bibber, Registration and Transportation Committee.

It is urged that all who plan to attend write to G. R. Blake, Westinghouse Electric Corporation, 507 Main Street, Worcester 8, Mass., to obtain registration material. Room reservations at the Sheraton Hotel may be obtained through the Registration Committee.

New York Section Projects Show Highly Successful Year

The New York Section of the AIEE has issued its annual report for the year ending May 31, 1950. This section has seven divisions; five are technical: basic science, communication, illumination, power and industrial, and transportation (air-land-marine); two are geographical: the New Jersey Division and the Hudson Valley Division. The latter, organized just two years ago, has grown from 30 to 128 members. Each division has its own chairman, officers, and committees. The total number of members of the Section, excluding student members, reached 5,050 on April 13, 1950.

Expenditures were $19,005, of which $6,550 was allotted from Headquarters. The additional two-thirds of the money was raised by the Section, over $12,000 from educational courses, and the balance from inspection trips and other activities.

The Section held 40 regular meetings, 2 round-table discussions, 2 exhibits, 12 inspection trips, and 3 social gatherings. The round-table discussions differ from meetings only in that they are held in groups of three each, in separate rooms on different topics, so the actual number of regular meetings was 46. In addition, 31 educational courses were given, each consisting of from 6 to 20 lectures, a total of 247 sessions. The grand total of all meetings, trips, lectures, and so forth, was 310, or 1.5 per day—more than one meeting per committee night for every day of the year!

The two television exhibits and symposiums arranged by a special committee under the guidance of the Communication Division were an interesting activity in a new field. One exhibit and the two symposiums were held in connection with the annual convention of the American Association for the Advancement of Science, with 1,710 attending, and the other exhibit was a part of the AIEE Winter General Meeting, with an attendance of 2,383. The Illumination Division's "Light Sorcery" meeting with Alston Rogers of the General Electric Company as speaker drew 1,725 people, of whom about 1,100 were AIEE members. This was probably the largest attendance at any New York Section meeting. Dr. Wallace E. Howell, New York City's "rain-maker," was the main speaker at the Hudson Valley Division's annual dinner meeting in Poughkeepsie, and much interest was shown in the meeting by the local press and radio stations.

The election of Section officers, held in accordance with the By-laws, resulted in these officers being chosen for 1950–51: J. D. Tebo, *Chairman;* J. P. Neubauer, *Vice-Chairman;* J. A. Parrott, *Secretary;* L. F. Stone, *Treasurer;* and F. B. Bramhall and J. R. Kerner, *Members-at-Large.*

District 2 Executive Committee Holds Meeting in Baltimore

The Middle Eastern District Executive Committee met at the Lord Baltimore Hotel, Baltimore, Md., on October 2, 1950, with Cyril G. Veinott presiding.

After Mr. Veinott outlined the business referred to the Board of Directors during the previous year and his activities as vice-president for the past year, Mr. William A. Dynes, the District Secretary, reviewed the 1949–50 prize paper competition conducted in District 2 (Middle Eastern) in which 76 papers were considered. This was followed by a discussion of the Section Growth awards to be made at the General Session on October 3rd.

The matter of the establishment of a district treasury was brought before the meeting and

Members of the Middle Eastern District Executive Committee and their guests met at the Lord Baltimore Hotel October 2 for a morning and an afternoon session. Front row, left to right: F. Knapp, R. L. Merrill, H. H. Henline, M. L. Lehman, C. G. Veinott (Vice-President of District 2), W. A. Dynes (Secretary of District 2), H. N. Blackmon, H. A. Dambly, J. S. Antel, D. S. Bender, J. M. Blackhall. Second row, left to right: F. Hamburger, J. W. Gore, W. Chase, L. E. Knapp, A. J. Maslin, D. L. Westhoefer, G. H. Ramandanes, H. L. Linsey, S. R. Warren, W. K. Denkhaus, H. R. Delahooke, J. M. Rodgers, C. B. Lewis, M. M. Morisuye, W. H. McNutt, W. A. Farris. Third row, left to right: L. N. Grier, J. R. Dorsey, R. V. Kelch, J. A. Hall, A. A. Johnson, J. J. FitzGibbon, F. B. Crider, L. H. Fox, D. L. Rexford, R. L. Dingle, W. B. Morton, A. L. Price, H. H. Sheppard

it was decided not to have such a treasury.

Mr. M. L. Lehman, District 2 Vice-Chairman, led a conference on membership activities, which was followed by a conference on section-branch co-operation and student activities led by Professor J. S. Antel, chairman of District 2 Committee on Student Activities.

Julius Strasbourger of Cleveland, Ohio, was nominated for Vice-President for the Middle Eastern District for the 2-year term beginning August 1, 1951, and J. G. Dinwiddie of Toledo was selected as the District 2 member of the Institute Nominating Committee.

The afternoon session of the meeting was divided into two conferences. The first, on section operation and management, was led by H. A. Dambly and the second, on programs, by H. N. Blackmon.

Prior to the District Executive Meeting a breakfast meeting of the newly formed District Advisory Committee was held. This committee was formed to assist in plans for more effective meetings of the District Executive Committee.

District 2 Prize Paper Competition Awards

The judging of papers in the District 2 (Middle Eastern) prize paper competition for 1949–1950 has been completed and first and second prizes, provided under the new Institute rules, have been awarded. First prize went to Mr. F. S. Beale of the Maryland Section for his paper on "A Low Noise and Distortion Audio Multiplexing Equipment with High Stability Carrier Supply." Second prize was taken by Mr. E. C. Barnes of the Cleveland Section, with his paper on "An Experimental Study of Induction Machine End Turn Leakage Reactance." These papers were selected as the best of those submitted in competition by authors from the District during the period covered.

Mr. Beale (A '33) is with the Communication Equipment Engineering Section of the Westinghouse Electric Corporation, Baltimore, Md., engaged in power-line carrier and microwave radio activities. He has been with the company since 1943, before which time he was with the Idaho Power Company. He is a graduate of the Armour Institute of Technology (now the Illinois Institute of Technology).

Mr. Barnes (M '43) is the Manager of Engineering of the Ashtabula Division of the Reliance Electric and Engineering Company of Cleveland, Ohio. He also is a special lecturer at the Case Institute of Technology, evening division. Mr. Barnes was graduated from Ohio University.

A total of 76 papers was reviewed by the judges in this contest, as compared with 41 for last year's competition which was carried on by means of a contribution from each section as Institute prizes were not available at that time. The judging was a gigantic task because of the number of papers and their uniform excellence. The committee, which is to be commended for its work, was composed of Wilbur R. Appleman, *Chairman*, H. R. Burns, L. J. Fritz, K. Y. Tang, and C. E. Warren.

Frederic S. Beale, winner of first prize in the District 2 prize paper competition

Award of certificates and the two prizes of $75.00 and $50.00 to the first and second prize winners respectively was made by Vice-President Veinott at the Middle Eastern District Meeting in Baltimore at the general session on October 3.

Conference on Electron Tubes for Computers

A 2-day conference on electron tubes for computers, under the sponsorship of the AIEE and the Institute of Radio Engineers, in collaboration with the Panel on Electron Tubes, will be held December 11–12, 1950, at the Haddon Hall Hotel in Atlantic City, N. J. The emphasis of the conference will be on reliability of tubes for use in digital computers, with some attention to be devoted to special tubes developed specifically for computers. Further information may be obtained by writing to the conference secretary, A. Lederman, Panel on Electron Tubes, Room 601, 139 Centre Street, New York 13, N. Y.

AIEE Chicago Section Announces Technical Paper Contest

The Chicago section of AIEE this year is conducting a local competition for a technical paper contest. The $100 provided by AIEE Headquarters will be divided into three prizes: first prize, $50; second prize, $30; third prize, $20. All papers will be considered for Institute and District awards, which could amount to $175 more.

Papers can be submitted in any of the following fields: Power, Industry, Communication, General Application and Science, and Electronics, and should be of value in electrical engineering.

To be considered for this year's contest, all papers must be submitted, in triplicate, to the Chicago Section Secretary by February 1, 1951. Competent members of the Chicago Section will act as judges. The three best papers will be orally presented in synopsis at the April 26, 1951, General Meeting to determine first, second, and third place winners.

For complete details regarding eligibility, basis of grading, entrance requirements, and so forth, see page 813 of the September 1949 issue of *Electrical Engineering*.

F. J. Mollerus Takes Over As Chairman of Richland Section

F. J. Mollerus, the new Chairman of the Richland Section of the AIEE, assumed his duties at the first meeting of the fall season, September 27, at Carmichael Junior High School. Fifty electrical engineers from South Central Washington and North Central Oregon were present at this dinner meeting. Mr. Mollerus outlined the program for the coming year.

Stressing the need for professional development programs for engineers, Mr. Mollerus said, "In the first year of the Richland Section, organization was developed; the second year was one of conolidation; and in this third year, the pro-essional development of the engineer will be emphasized."

The program for the meeting featured a alk by George R. Prout, Vice-President of he General Electric Company and General Manager of the Nucleonics Department. He cited the unusual progress of the Rich-and Section since its organization two years ago. Recalling his early acquaintance with Elihu Thompson, one of the founders of the General Electric Company, Mr. Prout contrasted the approximate methods of calculations of those days with the accuracy now possible. He stated, "The electrical engineer and the electrical industry have made great contributions to the economic progress of the nation in the past 70 years. The General Electric Company encourages the participation of engineers in the activities of engineering and scientific societies. Such participation fosters the professional development of the engineer, and such development contributes to the progress of the individual and the company."

Mr. Prout emphasized the necessity for engineers and the engineering societies of which they are members to interest themselves in matters of national importance. Citing the Engineers' Joint Council Report on National Water Resources as a good example of an activity in which engineers can make a substantial contribution to the national interests, Mr. Prout recommended it as worthwhile reading for all engineers.

Shown here are the new officers and members of the Executive Committee of the AIEE Richland Section. Left to right: E. P. Peabody, A. J. Erickson, and O. Mageehon, Members of Executive Committee; G. M. Clifton, Secretary-Treasurer; R. B. Crow, Vice-Chairman; and F. J. Mollerus, Chairman

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Communication Division

Committee on Communication Switching Systems. (*R. C. Davis, Chairman; John Meszar, Vice-Chairman; A. E. Frost, Secretary.*) This committee is working on the problems and techniques of telephone switching for small communities, including different aspects of the art. A symposium will be undertaken with representatives from four different companies. The committee feels that the subject of community dial offices is a highly appropriate one for the Fall General Meetings, since they are generally held in the midwest where a large number of such systems are in use. The committee is also at work planning a session which will have as its main topic some interesting information on modern aspects of switching for telecommunication. (See Winter General Meeting announcement, page 1028 of this issue.) A meeting of the full membership of the committee during this meeting is being planned.

General Applications Division

Committee on Production and Application of Light. (*E. H. Salter, Chairman; R. C. Putnam, Vice-Chairman; R. L. Oetting, Secretary.*) Due to the current interest in noise prevention in the operation of electric equipment, this committee has chosen as its subject "Measurement and Control of Audible Noise from Fluorescent Lamp Ballasts" for study and presentation to the membership. It is expected that ballast manufacturers, fixture manufacturers, lamp manufacturers, and consumers will participate in discussion on this subject at various technical sessions and committee meetings. Another major concern of this committee is the dissemination of information relative to progress in the production and application of light and of energy in the associated ultraviolet and infrared bands.

Industry Division

Committee on Industrial Power Systems. (*J. S. Gault, Chairman; H. G. Barnett, Vice-Chairman; S. A. Warner, Secretary.*) For greater effectiveness this committee has reorganized its subcommittee structure, resulting in seven subcommittees (*EE, Oct '50, pp 938–9.*) This committee sponsored jointly with the Committee on Power Generation a Special Technical Conference at Pittsburgh, Pa., known as the AIEE Power Conference. A special publication including the complete papers and discussions presented at the conference has been issued. The Subcommittee on Interior Wiring Designs for Commercial Buildings has prepared a special publication on this subject. It is hoped to get out a revised edition of the popular Red Book "Electric Power Distribution for Industrial Plants." This committee sponsored three conference sessions and a special technical conference during the past year and will have sessions at the Fall and Winter General Meetings.

Committee on Mining and Metal Industry. (*T. B. Montgomery, Chairman; A. C. Muir, Vice-Chairman; L. N. Grier, Secretary.*) The development of technical sessions around general themes by the committee has proved interesting and successful to date. As examples of this, three sessions were sponsored by the committee at the Summer General Meeting. The session on metals had as a dual theme the steel industry in the Los Angeles area and the aluminum industry in the West. There were two sessions on western mining applications.

As the activities of the committee, which is still young, have progressed, we have all become more aware of the service which can be rendered. Our Mining Group falls into two categories as a result of geographical location: the soft coal miners of the East and the hard rock miners of the West. Their problems are somewhat different.

Due to the small attendance of members of the committee from the East, a committee meeting was not held at Pasadena. A meeting was held, however, at Cleveland concurrently with the Association of Iron and Steel Engineers Convention September 26–29. A number of members of the Mining Subcommittee attended a meeting of the Underground Power Committee of the American Mining Congress at the Summit Hotel, Uniontown, Pennsylvania, on September 26. Mr. C. O. Wood, Chief Electrical Engineer for Goodman Manufacturing Company, Chicago, Ill., is liaison representative for the committee with the American Mining Congress. Mr. Wood replaced Mr. D. E. Renshaw in this assignment when the latter took an assignment in Turkey.

The Fall General Meeting normally is most convenient for attendance of a majority of our members and the largest committee program of the year will normally be planned at this time.

Work is under way on tabulation of standards available for the particular industries served by the committee.

Power Division

Committee on Rotating Machinery. (*W. R. Hough, Chairman; C. G. Veinott, Vice-Chairman; J. L. Fuller, Secretary.*) The Induction Machinery Subcommittee has been working closely with the Committee on General Industry Applications in developing papers on the subject of "Oil Industry Applications" for presentation before Institute meetings. It also cosponsored with the Power Generation Committee a session on "Power Plant Auxiliary Drives." The Insulation Subcommittee will jointly sponsor with the Power Generation Committee sessions on "Insulation of Rotating Machinery."

The Synchronous Machinery Subcommittee has under consideration a request from the ASA (American Standards Association) *C-50* Committee to prepare an operating guide for large synchronous equipment. This is to cover material which should be recorded for reference but which cannot properly be a part of the *C-50* standard or the test codes.

A general revision of AIEE Standard *43* on insulation resistance was concluded by the Insulation Subcommittee, and has been approved as a new standard.

The Test Code Co-ordinating Subcommittee is working closely with the ASA *C-50* Committee in an attempt to make AIEE Rotating Machinery Test Codes suitable for direct incorporation as the test code section of *C-50.*

The revision by the D-C Subcommittee of Table I of ASA *C-50* is moving smoothly toward acceptance by the Standards Committee. This will be followed by recommendation to ASA for final approval. This approval will represent the culmination of several years of active experimental activity and committee work to bring this temperature standard up to date.

Committee on Transmission and Distribution. (*I. W. Gross, Chairman; S. B. Crary, Vice-Chairman; R. E. Pierce, Secretary.*) Substantial progress has been made on a number of the projects mentioned in the last Committee Report (*EE, Feb '50, p 171*). The Capacitor Standard, which was completed as a committee activity, has been sent to the ASA for consideration as an ASA Standard. A bibliography on Power Capacitor literature is expected to be available in 1951. The survey of line outage causes on systems of 100 kv and above, undertaken jointly with the Edison Electric Institute, is progressing systematically. The causes of over 10,000 outages are being studied and a report on the project is expected in the summer of 1951.

In the distribution field, studies are being made on radial distribution systems, primary and secondary circuit designs, capacity as affected by diversity factor, and a bibliography on Underground Distribution Systems is being undertaken. A subject that is receiving some attention is Co-ordination of Distribution Circuit Protection.

In the lightning field, the bibliography on Lightning, which was substituted for a second volume of the Lightning book, including practically all important articles on lightning from 1936 to 1949 and its effect on electric systems, has been completed and copies can be obtained from the Institute.

Consideration is being given to the lightning protection of base mobile radio stations. Studies on various features in the transmission-line field are receiving attention.

Section and Branch Activities—

Annual Report for 1949–50

The following constitutes the annual report on Institute Section and Branch activities for the fiscal year which ended April 30, 1950. Similar information for three preceding fiscal years appears in *Electrical Engineering*, November 1949, pages 1001–7; November 1948, pages 1117–20; August 1947, pages 837–40.

Members of the 1949–1950 committees supervising the divisions of Institute activities covered by this report are

Sections—D. I. Anzini, *Chairman;* C. S. Purnell, *Vice-Chairman (East);* W. C. Smith, *Vice-Chairman (West);* F. S. Benson, *Secretary;* W. J. Barrett, F. S. Black, G. W. Bower, T. C. D. Churchill, Bradley Cozzens, H. A. Dambly, O. R. Enriquez, C. W. Fick, R. C. Horn, R. E. Kistler, C. P. Knost, C. W. Lethert, A. L. O'Banion, L. R. Patterson, F. H. Pumphrey, R. V. Shepherd, E. W. Stone, J. S. Strasbourger, H. H. Wagner, and, ex-officio, Chairmen of Sections.

Student Branches—F. O. McMillan, *Chairman;* F. W. Tatus, *Vice-Chairman;* Roland G. Porter, *Secretary;* Sterling Beckwith, C. H. Chinburg, A. G. Conrad, H. B. Duling, R. A. Galbraithe, E. W. Kane, J. H. Kuhlmann, Rodney C. Lewis, H. N. Muller, Jr., Louis T. Rader, E. A. Reid, G. D. Sheckels, Kenneth F. Sibila, E. W. Spring, Ralph W. Tapy, F. A. Wahlers, William G. Warren, B. S. Willis, and, ex-officio, Counselors of Student Branches.

Table I. Section Membership and Meetings During Year Ending April 30, 1950

Section	AIEE Members August 1949	AIEE Members August 1950	Number of Meetings	Total No. Meetings
Akron	118	137	9	9
Alabama	199	276	10	
Subsection: Mobile-Pensacola			6	16
Arizona	131	195	11	
Group: Technical			7	18
Arkansas	79	112	11	
Group: Technical			9	
Subsection: Northwest Arkansas			8	28
Arrowhead	43	50	10	10
Beaumont	81	85	15	15
Boston	833	924	9	
Group: Technical Discussion			19	
Subsection: New Hampshire			3	31
Canton	79	95	11	
Group: Electronics			3	14
Central Indiana	232	313	14	14
Chicago	1,587	1,844	4	
Groups: Basic Science			3	
Communications			4	
Electronics			5	
Industrial			5	
Power			5	26
Cincinnati	236	266	12	
Group: Technical Discussion			6	18
Cleveland	708	810	9	
Groups: Basic Science			4	
Motors and Control			8	
Power Generation and Distribution			8	29
Columbus	137	152	10	
Subsection: Zanesville			12	22

Table I (continued). Section Membership and Meetings During Year Ending April 30, 1950

Section	AIEE Members August 1949	AIEE Members August 1950	Number of Meetings	Total No. Meetings
Connecticut	490	536	8	
Group: Technical			11	19
Dayton	341	385	10	
Groups: Aeronautics			2	
Electronics			3	
Motors and Controls			4	
Power			2	
Subsection: Lima			7	28
Denver	367	442	12	
Groups: Communications			4	
Electrical Equipment			4	
Power Systems			6	
Subsection: Casper, Wyo			4	30
East Tennessee	415	333	12	
Subsection: Oak Ridge			6	18
Erie	130	167	12	
Group: Electronics			2	
Subsection: Ridgway			5	19
Florida	137	161	3	3
Fort Wayne	125	139	11	11
Georgia	220	255	15	
Subsection: Savannah			5	20
Houston	271	290	11	
Groups: Communications			1	
Geophysical			3	
Industrial Applications			2	
Subsection: Freeport			7	24
Illinois Valley	151	146	11	
Group: Technical			7	
Subsection: Sangamon			5	
Sangamon Technical Group			5	28
Iowa	187	202	7	
Subsection: Quad Cities			7	14
Ithaca	180	213	9	
Group: Discussion			7	
Subsection: Binghamton Area			5	
Binghamton Area Discussion Group			4	25
Kansas City	272	299	13	
Group: Technical			15	28
Lehigh Valley	324	373	9	9
Los Angeles	1,289	1,471	11	
Groups: Aircraft			7	
Electronics			6	
Power			6	
Subsection: Boulder City			9	39
Louisville	115	138	10	10
Lynn	266	298	20	20
Madison	75	88	8	8
Mansfield	74	82	8	
Group: Electronics			3	11
Maryland	626	674	12	
Groups: Communications			4	
Industrial Electronics			3	
Power			2	
Subsections: Eastern Shore			5	
Lancaster-York			6	32
Memphis	124	171	10	
Subsection: Nashville			6	16
Mexico	216	213	8	8
Miami	97	114	12	12
Michigan	805	845	7	
Groups: Round Table			2	
Electronics			4	
Industrial Power			1	
Instruments and Measurements			3	
Welding			2	
Subsection: Saginaw Valley			7	26

Table I (continued). Section Membership and Meetings During Year Ending April 30, 1950

Section	AIEE Members August 1949	AIEE Members August 1950	Number of Meetings	Total No. Meetings
Milwaukee	688	785	7	
Groups: Audio			1	
Basic Science			4	
Electric Machinery			3	
Electronics			3	
Power Application and Control			4	
Transmission and Distribution			3	
Subsection: Fox River Valley			9	34
Minnesota	279	352	9	
Groups: Commercial and Domestic Applications			1	
Communications			1	
Electronics			1	
Power			3	
Subsection: Red River Valley			11	26
Montana	90	123	7	
Subsections: Billings			9	
Great Falls			9	25
Montreal	296	324	9	
Subsection: Ottawa			1	10
Nebraska	108	140	9	9
New Mexico-West Texas	148	193	13	
Subsection: Albuquerque			8	21
New Orleans	246	309	10	
Group: Technical			5	
Subsections: Baton Rouge			5	
Jackson, Miss.			3	
Lake Charles			9	32
New York	4,894	5,245		
Groups: Basic Science			5	
Communications			12	
Illumination			5	
Power and Industrial			10	
Transportation			5	
Subsections: Hudson Valley			7	
New Jersey			6	50
Niagara Frontier	266	278	13	13
Niagara International	101	121	15	15
North Carolina	229	265	3	
Subsections: Charlotte			11	
Mid-State			4	18
Northeastern Michigan		105	2	2
North Texas	385	500	9	
Groups: Distribution Practices			3	
Electronics			1	
Industrial Practices			2	
Subsections: Central Texas			6	
Fort Worth			5	
West Central Texas			10	36
Oak Ridge		117	2	2
Oklahoma City	180	208	9	
Groups: Communications			3	
Electronics			3	
Industrial and Commercial Practices			3	
Power Systems			5	23
Ottawa		68	13	13
Panhandle Plains	131	171	9	
Groups: Industrial Practices			1	
Rotating Machinery			1	
Transmission and Distribution			2	13
Philadelphia	1,344	1,555	12	
Groups: Basic Science			3	
Communications			5	
Electronics			3	
Industrial Practices			3	
Instruments and Measurements			3	
Power Systems			3	
Subsection: Wilmington			14	46
Pittsburgh	1,050	1,202	14	
Subsections: Center County			11	
Johnstown			9	34
Pittsfield	283	326	12	12
Portland (Oreg.)	438	534	24	24
Providence	132	165	8	8
Richland	94	104	12	12
Rochester	214	234	22	
Groups: Communications			1	
Power			1	24
Rock River Valley	84	101	10	10
St. Louis	521	609	11	
Groups: Electronics			8	
Industrial Apparatus			6	
Industrial Power Practices			9	34
San Diego	157	159	11	
Groups: Atomic Energy			2	
Electrical Control			1	14
San Francisco	1,259	1,251	10	
Group: Technical			18	
Subsections: Fresno			8	
Sacramento			10	
San Jose			10	
Shasta			8	64
Schenectady	928	1,015	7	
Groups: Basic Science			3	
Generation and Transmission			3	
Industrial Power			3	
Personal Appraisal			2	18
Seattle	422	524	14	
Groups: Aircraft Technical			2	
Basic Sciences			3	
Electronics			2	
Power			4	
Transportation			3	
Subsection: Tacoma			7	35
Sharon	178	201	10	
Group: Technical			1	11
Shreveport	74	96	9	9
South Bend	102	117	14	14
South Carolina	122	147	2	
Subsections: Charleston			1	
Columbia			7	10
South Texas	163	205	10	
Group: Technical			5	
Subsection: Corpus Christi			8	23
Spokane	128	154	11	11
Springfield	88	95	10	
Group: Technical			8	18
Syracuse	237	252	9	
Subsection: St. Lawrence International			6	15
Toledo	117	129	7	7
Toronto	557	628	16	
Groups: Communications			3	
Discussion			10	
Subsection: Hamilton			9	38
Tulsa	139	160	9	
Group: Technical			2	11
Urbana	99	93	2	2
Utah	115	137	13	13
Vancouver	182	207	14	
Group: Discussion			5	19
Virginia	168	198	7	
Subsections: Hampton Roads			7	
Richmond			4	
Western Virginia			1	19
Washington	832	946	10	
Groups: Basic Science			3	
Communications			3	
Electricity as Applied to Basic Research			3	
Electronics			4	
Power			4	27
West Virginia	120	158	11	
Subsection: Tri-State			8	19
Western Virginia		90	3	3
Wichita	82	106	12	12
Worcester	88	103	8	8
	30,460	34,696		1,674

Total Sections, 87
Total technical groups, 103
Total Subsections, 51
Total attendance, 141,905

Table II. Branch Meetings Held During Year Ending April 30, 1950

Branch	Number
*Akron, University of	13
Alabama Polytechnic Institute	8
Alabama, University of	13
*Alberta, University of	6
*Arizona, University of	32
Arkansas, University of	11
British Columbia, University of	24
Brooklyn, Polytechnic Institute of	
Day Division	12
Evening Division	2
Brown University	12
*Bucknell University	8
California Institute of Technology	8
*California, University of	16
*Carnegie Institute of Technology	28
Case Institute of Technology	12
Catholic University of America	5
Cincinnati, University of	2
Clarkson College of Technology	12
Clemson A & M College	8
Colorado A & M College	16
*Colorado, University of	12
*Columbia University	4
*Connecticut, University of	9
Cooper Union	
Day Division	12
Evening Division	0
*Cornell University	10
Delaware, University of	2
*Denver, University of	12
*Detroit, University of	11
Drexel Institute of Technology	10
Duke University	7
Fenn College	5
*Florida, University of	10
George Washington University	6
Georgia Institute of Technology	13
Harvard University	5
Howard University	5
Idaho, University of	14
Illinois Institute of Technology	21
*Illinois, University of	10
*Iowa State College	11
Iowa, University of	28
Johns Hopkins University	21
Kansas State College	7
*Kansas, University of	9
Kentucky, University of	17
*Lafayette College	11
Lehigh University	10
Louisiana Polytechnic Institute	6
Louisiana State University	12
Louisville, University of	10
*Maine, University of	7
Manhattan College	4
*Marquette University	17
*Maryland, University of	7
*Massachusetts Institute of Technology	6
*Michigan College of Mining and Technology	9
Michigan State College	3
*Michigan, University of	6
Milwaukee School of Engineering	10
*Minnesota, University of	6
Mississippi State College	11
*Missouri School of Mines and Metallurgy	10
*Missouri, University of	7
Montana State College	11
*Nebraska, University of	10
Nevada, University of	13
*New Hampshire, University of	10
*New Mexico College of A & M Arts	14
New Mexico, University of	7
New York, College of the City of	13
*New York University	
Day Division	30
Evening Division	6
Newark College of Engineering	8
North Carolina State College	9
North Dakota Agricultural College	6
*North Dakota, University of	5

Table II (continued). Branch Meetings Held During Year Ending April 30, 1950

Branch	Number
*Northeastern University	21
*Northwestern University	2
Norwich University	4
*Notre Dame, University of	15
Ohio Northern University	22
*Ohio State University	14
*Ohio University	8
Oklahoma A & M College	8
*Oklahoma, University of	7
*Oregon State College	12
*Pennsylvania State College	12
*Pennsylvania, University of	9
Pittsburgh, University of	24
Pratt Institute	8
*Princeton University	5
Puerto Rico, University of	0
Purdue University	12
*Rensselaer Polytechnic Institute	8
*Rhode Island State College	9
Rice Institute	7
Rose Polytechnic Institute	13
*Rutgers University	10
Santa Clara, University of	5
South Carolina, University of	2
South Dakota School of Mines and Technology	7
South Dakota State College	8
*Southern California, University of	17
*Southern Methodist University	1
*Stanford University	9
Stevens Institute of Technology	0
Swarthmore College	1
*Syracuse University	8
Tennessee, University of	1
*Texas, A & M College of	7
*Texas Technological College	12
*Texas, University of	18
Texas Western College Sub-Branch	7
Toronto, University of	2
*Tufts College	14
*Tulane University	9
Union College	9
*Utah, University of	15
Vanderbilt University	19
Vermont, University of	11
Villanova College	11
Virginia Military Institute	5
*Virginia Polytechnic Institute	3
Virginia, University of	5
Washington, State College of	13
*Washington, University of	11
Washington University	8
*Wayne University	6
West Virginia University	4
Wisconsin, University of	11
*Worcester Polytechnic Institute	7
*Wyoming, University of	8
*Yale University	6
Total Branches, 130	1,318

* Joint AIEE-IRE Branches.

Table III. Section Meetings Held During Last Three Fiscal Years

	Fiscal Year Ending April 30		
	1948	1949	1950
Number of Sections	81	85	87
Number of meetings held	1,463	1,613	1,674
Average number of meetings	18	19	19
Total attendance	119,943	131,936	141,905
Average attendance per meeting	82	82	85

Table IV. Branch Meetings Held During Last Three Fiscal Years

	Fiscal Year Ending April 30		
	1948	1949	1950
Number of Branches	127	129	130
Number of meetings held	1,233	1,405	1,318
Average number of meetings	10	11	10
Total attendance	77,224	105,290	81,815
Average attendance per meeting	63	75	62

AIEE PERSONALITIES.....

R. J. Wiseman (A '16, F '27), Chief Engineer, The Okonite Company, Passaic, N. J., has been appointed Vice-President and Chief Engineer of the company. Dr. Wiseman joined the company in 1921 as a research engineer. He was born in Cambridge, Mass., on July 18, 1890, and received the degrees of Bachelor of Science (1912) and Doctor of Engineering (1915) from the Massachusetts Institute of Technology. The latter degree was changed to Doctor of Science in 1923. Previous to joining The Okonite Company, Dr. Wiseman had instructed at Massachusetts Institute of Technology and had worked as an engineer with the Western Union Telegraph Company and the National Conduit and Cable Company. Dr. Wiseman is actively serving the Institute as a member of the Insulated Conductors Committee, of which he has been a member since 1947. In past years he has served on the following committees: Technical Program (1945–46); Award of Institute Prizes (1945–46); Standards (1945–46); Transmission and Distribution (1939–45, Chairman 1945–47); Board of Examiners (1939–45); Applications to Marine Work and Marine Transportation (1937–43); Instruments and Measurements (1937–39); and Research (1931–39). He is a past-president of the Insulated Power Cable Engineers Association and a member of the National Society of Professional Engineers and the International Conference on Large Electric High-Tension Systems. He is also a United States representative on the International Electrotechnical Commission Advisory Committee Number 20.

R. J. Wiseman

E. T. Mahood (A '26, F '36), Chief Engineer, Kansas area, Southwestern Bell Telephone Company, Kansas City, Mo., has retired, but will continue working as a consulting telephone engineer. Mr. Mahood had been with the Southwestern Bell Telephone Company for 46 years. He was born in St. Louis, Mo., on August 3, 1887, and started working for Southwestern Bell Telephone Company in 1904 as a draftsman and cable inspector, and later did appraisal and depreciation study work. In 1927, he was put in charge of the engineering department at Kansas City. Mr. Mahood, during his career with the company, worked on problems relating to the merger of Bell and independent plants in a number of cities then in the dial-conversion phase. Mr. Mahood has actively served the Institute as Vice-President representing the Southwest District (number 7) from 1942 to 1944 and as a member of the following committees: Sections (1936–42, Chairman 1942–43, 1943–46); Planning and Co-ordination (1942–44); Communications (1942–44); and the Special Committee on District Boundaries (1943–44).

E. T. Mahood

B. H. Caldwell, Jr. (A '37, F '49), Section Engineer, General Electric Company, Schenectady, N. Y., has been named assistant manager of engineering, Large Motor and Generator Engineering Division, General Electric Apparatus Department. **D. E. Brainard** (A '30, M '38), Section Engineer, Large Motor and Generator Engineering Division, has been named division engineer of the Salient Pole Generating and Converting Division. **H. D. Snively** (A '35, M '44), Large Motor and Generator Engineering Division, has been named division engineer of the D-C Motors and Generators Division. **R. V. Shephard** (A '36, M '43), Section Engineer, Large Motor and Generator Engineering Division, has been named division engineer of the Synchronous Motor and Generator Division. **R. W. Wieseman** (A '18, M '26), Section Engineer, Large Motor and Generator Engineering Division, has been named division engineer of Insulations, High Frequency Sets Division. Mr. Caldwell and Mr. Wieseman are serving the Institute as members of the Rotating Machinery Committee.

J. F. Fairman (A '20, F '35), Vice-President, Consolidated Edison Company of New York (N. Y.), Inc., and Past President of AIEE (1949–50), has been appointed a member of the Committee on Ordnance of the Research and Development Board, Department of Defense. Mr. Fairman is serving the Institute as a member of the Executive Committee, the Board of Directors, the Board of Trustees, and as a member of the John Fritz Medal Board of Award. He is also an Institute representative on the United Engineering Trustees, Inc., and a member of the General Electric Educational Fund Committee and the Executive Committee of the United States National Committee of the World Power Conference. Mr. Fairman is also a member of the Engineers Joint Council.

W. H. Chase (M '42), Chief Engineer, Engineering Department, Ohio Bell Telephone Company, Cleveland, has been appointed Assistant Vice-President of the company. Mr. Chase was born in Cleveland, Ohio, on January 25, 1898, and was educated at Hiram College, Case School of Applied Science (now Case Institute of Technology), and Harvard University College of Engineering. Mr. Chase was first employed in the telephone industry with the Hiram Telephone Company. In successive years he worked for the Pacific Telephone and Telegraph Company, the New England Telephone and Telegraph Company, and, in 1926, joined the Ohio Bell Telephone Company as an engineer. In 1940, he was made responsible for co-ordinating the protection activities of the company during wartime. Mr. Chase is serving the Institute as Chairman of the Cleveland Section. He is a member of the Telephone Pioneers of America.

C. B. Broschart (A '42, M '43), Vice-President, Bradley Company, Inc., Philadelphia, Pa., has been elected President of the company. Mr. Broschart was born in Dushore, Pa., on August 12, 1898, and was graduated from Pennsylvania State College in 1921 with a Bachelor of Science degree in electrical engineering. He started his industrial career with the Northeast Electric Company, Rochester, N. Y., and after that was with the General Electric Company for a number of years. From 1925 to 1929, Mr. Broschart instructed in electrical engineering at the evening division at Drexel Institute of Technology, Philadelphia, Pa. In 1929, he joined the Bradley Company as an application engineer and has been with the company continuously since that time.

R. L. Palmer (A '39), Electronics Engineer, International Business Machine Corporation, Poughkeepsie, N. Y., has been made laboratory manager. He is a graduate of Union College and has been with the company since 1932. **R. T. Blakely** (A '36, M '43), assistant engineer, has been made assistant to the laboratory manager. Mr. Blakely has been with the company since 1935 and is a graduate of Rensselaer Polytechnic Institute. He also received a master's degree from The Polytechnic Institute of Brooklyn.

Robert Paxton (A '26, F '48), Manager, Transformer and Allied Product Divisions, Apparatus Department, General Electric Company, Pittsfield, Mass., has been elected a Vice-President of the company and named a manager of manufacturing policy. Mr. Paxton was graduated from Rensselaer Polytechnic Institute in 1923 and, in the same year, became associated with the General Electric Company. Following several previous promotions with the company, he was named works manager for the company in Philadelphia. In 1945, he became manager of the Pittsfield Apparatus Works and, in 1948, he was appointed manager of the Transformer and Allied Products Division.

R. E. McDonald (A '46), Superintendent of Radio-Electrical and Accessory Overhaul, Northwest Airlines, Minneapolis, Minn., has been appointed chief engineer for Mid-Continent Airlines, Inc., Minneapolis. Prior to his airline affiliations, Mr. McDonald served as an instructor of electronics at Harvard University and performed field service work in electronics for the Naval Research Laboratory in Washington, D. C. He is a member of the AIEE Committee on Air Transportation.

J. L. Fuller (A '37, M '45), Engineer in charge of Design, Ivanhoe Division, Reliance Electric and Engineering Company, Cleveland, Ohio, has been appointed to the post of technical co-ordinator with responsibility for engineering co-ordination of special drives, technical investigations, analysis of special projects, and direction of Reliance's experimental program. Mr. Fuller has been with the company for 14 years. He is serving the Institute as a member of the Rotating Machinery Committee.

L. E. Record (A '31), Supervisor, Engineering Development and Testing Laboratories, General Electric Company, Schenectady, N. Y., has been appointed division engineer, cathode-ray-tube division, Syracuse, N. Y. Mr. Record has been with General Electric since 1939, and is a graduate of the University of Kansas.

E. H. Lamberger (A '27, M '48), Mining, Petroleum, and Chemical Section, Industry Engineering Department, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been appointed assistant to the manager of the patent department of the company. Mr. Lamberger has been with Westinghouse since 1921 and was graduated from Ohio State University in 1921 with an electrical engineering degree.

C. S. Allen (A '31, M '37), Vice-President and General Manager, A. O. Smith Electrical Manufacturing Company, Los Angeles, Calif., has been appointed general manager of the Star-Kimble Motor Division of Miehle Printing Press and Manufacturing Company, Bloomfield, N. J. Prior to his association with A. O. Smith, Mr. Allen was with the General Electric Company for 16 years.

J. H. Howard (A '41), consulting engineer, electronic control systems, has been appointed to the staff of the Research Division, Burroughs Adding Machine Company, Philadelphia, Pa. Mr. Howard is a member of the Institute of Radio Engineers and Sigma Xi.

R. R. Peck (A '37, M '44), Engineer, System Planning, Southern California Edison Company, Los Angeles, has been appointed apparatus engineer for the West Coast Division of the Line Material Company, Milwaukee, Wis. The West Coast Division includes the states of California, Arizona, and portions of Oregon and Nevada.

J. L. Sherwin (M '30, F '49), Chief Electrical Engineer, Arthur G. McKee and Company, Cleveland, Ohio, has resigned to re-establish his private practice of consulting electrical engineering services in Cleveland.

W. C. Harris (M '47), Designing Engineer, Apparatus Department, General Electric Company, Erie, Pa., has been appointed manager of engineering of the Locomotive and Car Equipment Divisions of the company's Apparatus Department. Mr. Harris has been with General Electric since 1911 except for a period of service as a first lieutenant during World War I.

J. A. Tyvand (M '37, F '45), Chief Electrical Engineer, Knappen, Tippetts, Abbett Engineering Company, New York, N. Y., has joined Ebasco Services, Inc., New York, N. Y., as a member of the consulting electrical engineering staff. Mr. Tyvand had been engaged in a study of the economics, design, and construction for the electrical development of valley projects in Turkey and Haiti prior to his association with Ebasco Services, Inc.

L. R. Wanner (A '33), Manufacturing Superintendent, Sylvania Electric Products, Inc., has been appointed plant manager in charge of plastics operations for the Parts Division. Prior to joining Sylvania in 1948, Mr. Wanner was associated with Hugh H. Eby, Inc., of Philadelphia, Pa.

F. W. McStay (A '47), Transformer Sales Section, Line Material Company, Zanesville, Ohio, has been appointed apparatus engineer in the company's North Central Division, which includes the states of Wisconsin, Minnesota, South Dakota, North Dakota, and part of Iowa. Mr. McStay joined the company in 1947.

F. A. Faron (A '21, M '27), District Manager, Industrial Division, Apparatus Department, General Electric Company, New York, N. Y., has been appointed New York district manager of the Apparatus Department. Mr. Faron has been with General Electric since 1916 and was named New York district manager of the industrial division in 1946.

R. C. Hanna (A '39), Assistant Manager of Sales, Fractional-Horsepower Motor Divisions, General Electric Company, Fort Wayne, Ind., has been appointed manager of sales for the Fractional-Horsepower Motor Divisions. Mr. Hanna has been with General Electric since 1929 except for a period of time during World War II when he was with the War Production Board.

J. J. Miller (A '48), Sales Engineer, General Electric Company, St. Louis, Mo., has been appointed manager of the industrial division of the company's Apparatus Department Mid-States District in St. Louis. Mr. Miller has been with General Electric since 1937, except during the period 1941 to 1946, when he served as a major in the Army of the United States.

T. L. Mayes (A '35, M '41), Works Engineer, Engineering Department, General Electric Company, Oakland, Calif., has been appointed manager of the Lynn, Mass., Motor Engineering Division of the company's Small and Medium Motor Divisions.

R. L. Goetzenberger (A '17, F '48), Vice-President, Brown Instrument Division, Minneapolis-Honeywell Regulator Company, Washington, D. C., has been elected chairman of The Citizens Federal Committee on Education, a lay advisory committee to the United States Commissioner of Education.

OBITUARY • • • •

Frank Robert McBerty (A '01, M '05, F '18, Member for Life), Chairman of the Board, North Electric Manufacturing Company, Galion, Ohio, died February 19, 1950. Mr. McBerty was born in Sharon, Pa., on February 14, 1868. He entered the employ of the Western Electric Company, Chicago, Ill., in 1887, and was with the company for 30 years. While at Western Electric he was successively in charge of switchboard engineering, patent work, a special laboratory in New York, and the development of the Western Electric Company's dial-telephone systems for use in European countries. After leaving the employ of Western Electric, Mr. McBerty became associated with the North Electric Manufacturing Company. From 1921 to 1949, he was president of the company and, in 1949, he was made chairman of the board of the company. Mr. McBerty held over 170 telephone patents. He served the Institute as a member of the Communication Committee from 1937 to 1941. He was also a member of the British Institution of Electrical Engineers.

Edward Hardenbergh Waldo (A '07, M '12, Member for Life), retired, died August 30, 1950. Mr. Waldo had been with the University of Illinois since 1907 and, at the time of his retirement, was an associate professor emeritus. He was born in Hornellsville (now Hornell), N. Y., on March 5, 1866, and received a Bachelor of Arts degree from Amherst College in 1888 and a mechanical engineering degree from Cornell University in 1890. He started his industrial career in 1890 with the Thomson Houston Company at Lynn, Mass., and with the Thomas Houston International Company in Montreal, Quebec, Canada. In 1892, Mr. Waldo was put in charge of the repair shops of the General Electric Company in New York, N. Y. From 1894 to 1904, he was an instructor in electrical engineering at the University of Pennsylvania, Philadelphia. In 1904, he accepted a position as an engineering designer with Crocker-Wheeler Company. In 1907 he became assistant professor of electrical engineering at the University of Illinois. He served the Institute as chairman of the Urbana, Ill., Section from 1931 to 1932. Mr. Waldo was a member of the Illuminating Engineering Society, Phi Beta Kappa, Tau Beta Pi, and Eta Kappa Nu.

George Walter McIver, Jr. (A '08, F '26, Member for Life), Chief Engineer, Toledo (Ohio) Edison Company, died July 24, 1950. Mr. McIver was born in Greenville, S. C., on July 27, 1884, and received the degree of Bachelor of Science from Clemson College in 1904 and the degree of Mechanical Engineer from Cornell University in 1906. Mr. McIver started his public utility career with the Public Service Company of Newark, N. J., and in 1913 he became resident engineer in charge of construction with the E. W. Clark Management Corporation of Columbus, Ohio. In 1917, he became general superintendent and chief engineer for the Wisconsin-Minnesota Light and Power Company, Eau Claire. From 1917 to 1919, Mr. McIver was a captain in the Army of the United States and supervised the rebuilding of utility systems in France and Germany. Then he became associated with Henry L. Dougherty and Company, New York, N. Y., and, in 1923, he became assistant manager of the electric department of the Toledo Edison Company. Mr. McIver successively attained the positions of general superintendent and chief engineer with the company. He served the Institute as a member of the Electric Machinery and Rotating Machinery Committees from 1946 to 1949. He was a member of the American Welding Society.

Frank Sawford (A '10, M '40, Member for Life), consulting engineer, Vancouver, British Columbia, died August 24, 1950. Mr. Sawford was born on February 12, 1875, in Normanton, Yorkshire, England, and was educated at the Welwyn Herts School and the Normanton Continuation School. From 1891 to 1906 Mr. Sawford was associated with various consulting engineering firms and electrical manufacturing concerns in England. From 1906 to 1911, he was with the Dominion Iron and Steel Company, Ltd., of Sydney, Nova Scotia, Canada. In successive years, he worked as chief engineer for Canadian Collieries (Dunsmuir) Ltd., Vancouver, and the Taylor Engineering Company, Ltd., Vancouver. Since 1920, Mr. Sawford had been a consulting electrical and mechanical engineer in Vancouver. He was a member of the American Society of Mechanical Engineers.

Laurence Albert Gary (A '12, M '26, Member for Life), retired, died August 23, 1950. Mr. Gary was born in Zanesville, Ohio, on June 5, 1883, and was graduated from Case School of Applied Science (now Case Institute of Technology) in 1904 with a Bachelor of Science degree in electrical engineering. He started with the Western Electric Company in 1905 and, after several years with the company, Mr. Gary transferred to The Pacific Telephone and Telegraph Company where he worked on equipment and transmission engineering. At the time of his retirement in 1945 he was exchange transmission engineer for the Northern California and Nevada area. Subsequent to his retirement, he spent a year with the Mutual Telephone Company of Hawaii. Mr. Gary was a member of the Telephone Pioneers of America.

Harry Oscar Warner (M '27), Director of Electrical Engineering, University of Detroit (Mich.), died September 16, 1950. Professor Warner was born in Royalton, Pa., on January 10, 1890, and received a Bachelor of Science degree from Pennsylvania State College in 1914, an electrical engineering degree from the same college in 1934, and a Master of Science degree from the University of Michigan in 1936. Previous to the start of his teaching career, Professor Warner was associated with the Pennsylvania Steel Company and the Bell Telephone Company of Pennsylvania. He was an instructor at George Washington University, Washington, D. C., from 1920 to 1921. In 1921, Professor Warner became an instructor at the University of Detroit and was with the University continuously until his death. He had served the Institute as a Student Branch Counselor since 1930. Professor Warner was a member of the Illuminating Engineering Society and the American Society for Engineering Education.

Stanley Clayton Howard Hill (A '38), Assistant to the Superintendent, Substation Division, Generating and Transmission Department, Shawinigan Water and Power Company, Shawinigan Falls, Quebec, Canada, died September 4, 1950. Mr. Hill had been with the company for 27 years. He was born in Richmond, Quebec, on July 5, 1896, and received the degree of Bachelor of Science in electrical engineering from McGill University in 1921. After a short period of work for other firms he joined the Shawinigan Engineering Company in 1923 and, in 1924, he was transferred to the Shawinigan Water and Power Company. In 1938, Mr. Hill was made superintendent of the fourth district of the company in Victoriaville, Quebec, and in 1950, he became assistant to the superintendent at Shawinigan Falls. He was a member of the Engineering Institute of Canada, the Corporation of Professional Engineers of the Province of Quebec, and the Canadian Electrical Association.

John Bragdon Williams (A '40), Electrical Design Engineer, Pioneer Service and Engineering Company, Chicago, Ill., died September 2, 1950. Mr. Williams was born on February 12, 1918, in Decatur, Ill., and was graduated from the University of Louisville (Ky.) with a Bachelor of Science degree in electrical engineering in 1939. He was employed by the Louisville (Ky.) Gas and Electric Company as assistant electrical engineer in 1937. From 1946 to 1947, Mr. Williams worked as a field engineer on electronic heating equipment for the Girdler Corporation, Louisville, Ky. He entered the employ of the Pioneer Service and Engineering Company in 1947.

MEMBERSHIP • • •

Recommended for Transfer

The board of examiners at its meeting of September 21, 1950, recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the Secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

To Grade of Fellow

Atwell, C. A., elec. design engr., Westinghouse Elec. Corp., East Pittsburgh, Pa.

Bailey, A., telephone engr., American Tel. & Tel. Co., New York, N. Y.
Benson, F. S., asst. engr., Pacific Gas & Elec. Co., San Francisco, Calif.
Brosnan, T. J., western div. engr., Niagara Mohawk Power Corp., Buffalo, N. Y.
Brown, M. K., system supervising engr., Niagara Mohawk Power Corp., Buffalo, N. Y.
Damon, J. C., principal engr., Jackson & Moreland, Boston, Mass.
Frazier, R. H., assoc. prof., Massachusetts Institute of Technology, Cambridge, Mass.
Geiger, J. M., elec. engr., Niagara Mohawk Power Corp., Buffalo, N. Y.
Hall, A. C., assoc. prof. elec. engg; director, dynamic analysis & control lab, Massachusetts Institute of Technology, Cambridge, Mass.
Harrington, H. L., system engr., Niagara Mohawk Power Corp., Buffalo, N. Y.
Hubbard, M. M., asst. director, nuclear science & engg. lab., Massachusetts Institute of Technology, Cambridge, Mass.
Johnson, A. A., mgr., central station engg., Westinghouse Electric Corp., East Pittsburgh, Pa.
Jucarone, N. T., marine engr., bureau of ships, Navy Dept., Washington, D. C.
Kammerman, J. O., head, elec. engg. dept,, South Dakota School of Mines & Technology, Rapid City, S. D.
Knight, F. D., vice pres., Hartford Electric Light Co.; Connecticut Power Co., Hartford, Conn.
Knowlton, A. D., systems engg. director, Bell Telephone Labs., Inc., New York, N. Y.
Lange, E. O., elec. engg. prof. & dept. head, Drexel Institute of Technology, Philadelphia, Pa.
Loud, F. M., engr., Jackson & Moreland, Boston, Mass.
Lusignan, J. T., Jr., executive engr., The Ohio Brass Co., Mansfield, Ohio
Matsch, L. W., elec. engg. prof., Illinois Institute of Technology, Chicago, Ill.
McCurley, J. B., Jr., chief, power div., Rural Electrification Administration, Washington, D. C.
Merrill, F. W., consulting engr., General Electric Co., Ft. Wayne, Ind.
Rutter, A. R., mgr. of engg., meter div., Westinghouse Electric Corp., Newark, N. J.
Sheals, V. A., mgr. of engg., wire & cable div., General Electric Co., Schenectady, N. Y.
Wright, S. H., elec. engr., Ebasco Services, Inc., New York, N. Y.
Yerger, L. K., research & testing supervisor, Niagara Mohawk Power Corp., Buffalo, N. Y.

26 to grade of Fellow

To Grade of Member

Aichele, P. F., technical writer, Sperry Gyroscope Co., Great Neck, N. Y.
Alberti, A. C., industrial engr., City Public Service Board, San Antonio, Tex.
Anderson, W. T., elec. engg. instructor, Michigan College of Mining & Technology, Houghton, Mich.
Arguelles, C. R., consulting engr., San Juan letran de #84, Mexico, D. F.
Baker, P. K., engr., Ohio Bell Tel. Co., Cleveland, Ohio
Barden, J. F., Jr., outside plant engr., Carolina Tel. & Tel. Co., Tarboro, N. C.
Belayeff, O. I., supt., engg. dept., Manila Electric Co., Manila, Philippines
Bongale, R. M., supt., testing dept., Tata Hydro-Electric Cos., Bombay, India
Brader, D. W., field application engr., I-T-E Circuit Breaker Co., St. Louis, Mo.
Burdett, J. C., elec. design engr., Westinghouse Electric Corp., Lima, Ohio
Bydal, C. B., senior engr., Commonwealth Edison Co., Chicago, Ill.
Cheatham, R. E., Jr., elec. engr., Mississippi Power & Light Co., Jackson, Miss.
Collins, W. G., protection engr., Pacific Tel. & Tel. Co., San Francisco, Calif.
Cook, E. F. I., elec. engr., British Electricity Authority, Haywards, Heath, Sussex, England
Cooper, A. J., mgr., empire region, Allis-Chalmers Mfg. Co., New York, N. Y.
Creager, F. L., supt. model shop, RCA Laboratories, Princeton, N. J.
Cross, G. W., sales engr., industrial div., General Electric Co., New York, N. Y.
Cummings, W. J., retired lieut. colonel, AUS., 5835 Avenida Commercial, LaJolla, Calif.
Davis, R. S., asst. to vice pres., Bull Dog Electric Products Co., Detroit, Mich.
deQuevedo, J. L. G., assoc. prof.; head, elec. engg. dept., College of Agriculture & Mechanic Arts, Mayaguez, P. R.
Derrick, C. L., engg. supt., The Hartford Electric Light Co., Hartford, Conn.
Douglas, C., partner, Douglas & Mansfield, C.E., Houston, Tex.
Epple, R. J., project design & construction engr., American Viscose Corp., Philadelphia, Pa.
Eppley, I. C., asst. mgr., elec. engg. div., Dayton Power & Light Co., Dayton, Ohio
Fanning, L. G., elec. distribution engr., Washington Water Power Co., Spokane, Wash.
Farrar, H. K., staff engr., The Pacific Tel. & Tel. Co., Los Angeles, Calif.
Faulkingham, L. H., asst. distribution supt., New Hampshire Gas & Electric Co., Portsmouth, N. H.
Feigenbaum, A. V., training supervisor, General Electric Co., Schenectady, N. Y.
Fletcher, S. H., district supt., Virginia Electric & Power Co., Newport News, Va.
Foster, C. M., elec. engr., Chas. T. Main, Inc., Boston, Mass.
Fulton, R. B., sales engr., Allis-Chalmers Mfg. Co., Detroit, Mich.
Gieszczykiewicz, S. E., senior elec. engr., Associated Electrical Industries, Calcutta, India
Gilman, S., senior elec. engr., American Machine & Foundry Co., Brooklyn, N. Y.
Glavinovich, L. V., assoc. construction inspector, University of California, Berkeley, Calif.
Goodell, C. E., chief engr., Russell Mfg. Co., Caro, Mich.
Haltrecht, A., National Research Council of Canada, Ottawa, Ont., Can.
Harris, H. G., district engr., Tennessee Valley Authority, Jackson, Tenn.
Heckert, R. B., elec. equipment purchaser, C. F. Braun & Co., Alhambra, Calif.
Hendry, A. J., general signal inspector, Northern Pacific Railway Co., St. Paul, Minn.
Herrmann, J. A., vice pres., Bull Dog Electric Products Co., Detroit, Mich.
Hoffman, O. W., induction motor engr., General Electric Co., San Jose, Calif.
Hutchins, S. E., elec. manufacturing engr., Western Electric Co., Chicago, Ill.
Imm, R. A., instructor, elec. engg. dept., University of Wisconsin, Madison, Wisc.
Johnson, C. E., equipment maintenance engr., Southern California area, Pacific Tel. & Tel. Co., Los Angeles, Calif.
Johnson, J. H., asst. prof., State College of Washington, Pullman, Wash.
Josse, H., chief engr., elec. div., Production Thermique d'Electricite de France, Paris, France
Kaminski, J., Jr., head, transmission lines unit, Rural Electrification Administration, Washington, D. C.
Karve, S. G. V., project officer, Central Electricity Commission, Cleremont, Simla, India
Keast, P., master mechanic, Empire Star Mines Co., Ltd., Grass Valley, Calif.
Kesler, J. P., elec. engr., Black & Veatch, C. E., Kansas City, Mo.
MacGregor, R. R., engr., American Tel. & Tel. Co., New York, N. Y.
Mahanti, P. C., prof. & head, Applied Physics Dept., University of Calcutta, West Bengal, India
Manning, H. M., elec. engr., light dept., City of Tacoma, Tacoma, Wash.
Markers, H. W., engr., Commonwealth Edison Co., Chicago, Ill.
Markese, M. S., application engr., Delta-Star Electric Co., Chicago, Ill.
Markese, S. D., design engr., Delta-Star Electric Co., Chicago, Ill.
Markusen, D. L., research engr., Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.
Marshall, J. W., elec. engr., General Electric Co., Los Angeles, Calif.
Marshall, R. T., chief dispatcher, Houston Lighting & Power Co., Houston, Tex.
McMullin, E. K., engg. group leader, North American Aviation, Inc., Los Angeles, Calif.
McRae, J. W., transmission development director, Bell Telephone Laboratories, Murray Hill, N. J.
Miller, R. H., communications engr., Pacific Gas & Electric Co., San Francisco, Calif.
Miller, W. S., application engr., I-T-E Circuit Breaker Co., Philadelphia, Pa.
Miller, W. S., local office transportation engr., General Electric Co., Houston, Tex.
Mintz, N. M., sales & application engr., N. M. Mintz & Associates, Chicago, Ill.
Nagel, T. J., American Gas & Electric Service Corp., New York, N. Y.
Nau, R. H., asst. prof., University of Illinois, Urbana, Ill.
Nelson, P. H., assoc. prof., University of Florida, Gainesville, Fla.
Notley, J. A., overhead lines & power supervisor, Key System Transit Lines, Oakland, Calif.
Olson, J. H., engr., The Pacific Tel. & Tel. Co., Seattle, Wash.
Pentecost, J. R., genl. mgr., Choctawhatchee Electric Cooperative, Inc., DeFuniak Springs, Fla.
Purdy, R. T., asst. supt., power supply, Commonwealth Edison Co., Chicago, Ill.
Reid, W. S., Jr., asst. project engr., The Ralph M. Parsons Co., Los Angeles, Calif.
Reifschneider, P. J., elec. engr., General Electric Co. Philadelphia, Pa.
Roberson, L. N., mgr., L. N. Roberson Co., Seattle, Wash.
Rose, L. H., prof. & head, elec. engg. dept., University of Dayton, Dayton, Ohio
Rudahl, A. E., product dev. engr., Landers, Frary & Clark, New Britain, Conn.
Schaefer, C. A., development engr., Square D Co., Milwaukee, Wis.
Scheick, E. H., asst. chief engr., American Smelting & Refining Co., New York, N. Y.
Schulman, H. M., pres., Schulman Electric Co., Chicago, Ill.
Scott, G. H., asst. prof. of elec. engg., University of Arkansas, Fayetteville, Ark.
Sears, J. W., trunk engr., Indiana Bell Telephone Co., Indianapolis, Ind.
Shiozawa, S., engr., Rural Electrification Administration, Washington, D. C.
Skidmore, W. H., chief, aircraft instrument engg. group, Weston Electrical Instrument Corp., Newark, N. J.
Southerland, J. W., project engr., Tennessee Valley Authority, Chattanooga, Tenn.
Steen, W. J., senior project engr., Motorola, Inc., Chicago, Ill.
Stuehler, C. M., engr., Public Service Electric & Gas Co. of New Jersey, Newark, N. J.
Styner, P. M., elec. engr., Empire District Electric Co., Joplin, Mo.
Swami, T. V., chief engr. & secy., The Mahihir Jute Mills, Ltd., Sahjanwa, Gorakhpur, India
Tice, H. W., vice pres., Southern California Edison Co., Los Angeles, Calif.
Vallin, G. L., section engr., General Electric Co., Pittsfield, Mass.
Vogel, C. E., design engr., Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.
Ward, R. P., asst. to dean of engg., Texas A & M College, College Station, Tex.
Warner, J. L., asst. prof., Tufts College, Medford, Mass.
Watson, H. M., supervisory engr., Westinghouse Electric Corp., Pittsburgh, Pa.
Watts, T. O., factory mgr., The Hoover Co., Ltd., Hamilton, Ont., Can.
Wheeler, D. B., development engr., General Electric Co., Schenectady, N. Y.
Wisman, F. O., new devices development engr., Bendix Aviation Corp., South Bend, Ind.
Zimmermann, K. H., senior engr., Federal Tel. & Radio Corp., Nutley, N. J.
Zipse, A. E., engr., station design div., Commonwealth Edison Co., Chicago, Ill.

100 to grade of Member

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should so notify the Secretary before November 25, 1950, or January 25, 1951, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Attura, G. M., Industrial Control Co., New York, N.Y.
Congilose, F. X., Board of Transportation, New York, N.Y.
Disney, V. H., Armour Research Foundation, Chicago, Ill.
Faulk, D. P., Raytheon Manufacturing Co., Newton, Mass.
Fukuda, K., Kanto Electric Supply Co., Tokyo, Japan
Harris, C. E., Corps of Engrs., Nashville, Tenn.
Hess, P. M., Pennsylvania Water & Power Co., Lancaster, Pa.
Hopper, R. F., Westinghouse Elec. Corp., St. Louis, Mo.
Immer, W. L., General Elec. Co., St. Louis, Mo.
Inouye, G., Chubu Haiden K. K., Nagoya, Japan
Ipponmatsu, T., Kansai Electric Supply Co., Osaka, Japan
Jones, N. S., H.E.P.C. of Ontario, Kipling Transformer Station, Islington, Ont., Canada
Kapell, S. M., Westinghouse Elec. Corp., Philadelphia, Pa.
Kenyon, W. B., Rochester Gas & Elec. Corp., Rochester, N.Y.
Lefier, J. T., Bureau of Indian Affairs, Window Rock, Ariz.
Mori, H., Japan Elec. Generation & Transmission Co., Ltd., Tokyo, Japan
Osborn, C. F. (re-election), Pennsylvania Crusher Co., St. Louis, Mo.
Rifkin, S., General Elec. Co., Schenectady, N.Y.
Rush, F. M., Jr., Toledo Edison Co., Toledo, Ohio
Trier, S. S., North American Aviation, Los Angeles, Calif.
Tsao, C. Y., City College of New York New York, N.Y.
Virkar, D. V., L. D. Engg. College, Ahmedabad, Bombay State, India
Winchester, A. J., Jr., Westinghouse Elec. Corp., Buffalo, N.Y.

23 to grade of Member

OF CURRENT INTEREST

Congress Establishes New Values for Electrical and Photometric Units

By an act approved July 21, 1950 (Public Law 617), the 81st Congress has given formal statutory sanction to a revision of the practical system of electrical units. In large part, the values adopted for these units resulted from research by the National Bureau of Standards and the present legislation was proposed by the Bureau. The changes in the magnitude of the units are small, in no case larger than 1/20 of one per cent, but the new law puts the values on a clear and unambiguous basis which assures the closest practicable agreement between electrical and mechanical units.

The law previously in effect, enacted 56 years ago, included double definitions of the units. There were no central standards laboratories at that time and to enable any competent laboratory to set up valid electrical standards the United States law, as well as international agreements, prescribed certain devices to produce three basic units. The ampere was defined by the rate of deposition of silver in a voltameter or coulometer, the ohm as the resistance of a specified column of mercury, and the volt as a specified fraction of the electromotive force of a certain type of standard cell.

It was later found that these conventional standards did not produce exactly the intended values of the units. Technical and scientific developments, including the use of electrical instruments for many kinds of measurement, made it increasingly inconvenient to have electrical units not strictly consistent with those of mechanics. Furthermore, national standards laboratories were established in all of the larger industrial countries. These laboratories maintain the basic standards of measurement so that the need for the old system of reproducible electrical standards has disappeared.

Recognizing these changed conditions, the AIEE in 1928 proposed a return to the basic absolute units. Twenty years of research and negotiation were required to bring about unanimous international action to this end.

The new Act is similar to the old law in defining the fundamental practical units as multiples of the units of the centimeter-gram-second electromagnetic system. In fact, however, they are also component parts of the meter-kilogram-second system which is being widely accepted in textbooks and in engineering practice. Two sections of the Act define the basic photometric units, the candle and the lumen, which were not previously defined by law.

The provisions of the law are as follows:

That from and after the date this Act is approved, the legal units of electrical and photometric measurement in the United States of America shall be those defined and established as provided in the following sections:

Section 2. The unit of electrical resistance shall be the ohm, which is equal to one thousand million units of resistance of the centimeter-gram-second system of electromagnetic units.

Section 3. The unit of electric current shall be the ampere, which is one-tenth of the unit of current of the centimeter-gram-second system of electromagnetic units.

Section 4. The unit of electromotive force and of electric potential shall be the volt, which is the electromotive force that, steadily applied to a conductor whose resistance is one ohm, will produce a current of one ampere.

Section 5. The unit of electric quantity shall be the coulomb, which is the quantity of electricity transferred by a current of one ampere in one second.

Section 6. The unit of electrical capacitance shall be the farad, which is the capacitance of a capacitor that is charged to a potential of one volt by one coulomb of electricity.

Section 7. The unit of electrical inductance shall be the henry, which is the inductance in a circuit such that an electromotive force of one volt is induced in the circuit by variation of an inducing current at the rate of one ampere per second.

Section 8. The unit of power shall be the watt, which is equal to 10,000,000 units of power in the centimeter-gram-second system and which is the power required to cause an unvarying current of one ampere to flow between points differing in potential by one volt.

Section 9. The units of energy shall be

Stainless-Steel Turbine Runner

A stainless-steel runner for a hydraulic turbine is the framework of this lighting effect in a steel foundry of the Bethlehem Steel Company in Bethlehem, Pa. The silhouetted workman is using a grinding wheel to finish the 16 blades of the runner, which will be rotated by water

Future Meetings of Other Societies

American Society of Mechanical Engineers. 19th National Exposition of Power and Mechanical Engineering. November 27–December 2, 1950, Grand Central Palace, New York, N. Y.

American Standards Association. Annual Meeting November 27–29, 1950, Waldorf-Astoria Hotel, New York, N. Y.

Hydraulic Institute. December 3–5, 1950, Seaview Country Club, Absecon, N. J.

Industrial Management Society. 14th Annual National Time, Motion, and Management Clinic. November 2–3, 1950, Sheraton Hotel, Chicago, Ill.

National Electrical Manufacturers Association. November 13–16, 1950, Chalfonte-Haddon Hall, Atlantic City, N. J.

National Research Council. 1950 Conference on Electrical Insulation. November 1–3, 1950, Pocono Manor Inn, Pocono Manor, Pa.

National Society of Professional Engineers. Fall Meeting. November 3–4, 1950, Little Rock, Ark.

Radio Fall Meeting. Annual meeting of radio engineers, sponsored by the Institute of Radio Engineers and the Radio-Television Manufacturers Association's Engineering Department. October 30–November 1, 1950, Hotel Syracuse, Syracuse, N. Y.

(a) the joule, which is equivalent to the energy supplied by a power of one watt operating for one second, and (b) the kilowatt-hour, which is equivalent to the energy supplied by a power of 1,000 watts operating for one hour.

Section 10. The unit of intensity of light shall be the candle, which is 1/60 of the intensity of one square centimeter of a perfect radiator, known as a "black body," when operated at the temperature of freezing platinum.

Section 11. The unit of flux of light shall be the lumen, which is the flux in a unit of solid angle from a source of which the intensity is one candle.

Section 12. It shall be the duty of the Secretary of Commerce to establish the values of the primary electric and photometric units in absolute measure, and the legal values for these units shall be those represented by, or derived from, national reference standards maintained by the Department of Commerce.

Section 13. The Act of July 12, 1894 (Public Law 105, 53rd Congress), entitled "An Act to define and establish the units of electrical measure," is hereby repealed.

Bell Laboratories Develop Improved Type of Deposited Carbon Resistor

An improved type of deposited carbon resistor, expected to find widespread use in the communications and electronic fields, has been developed at Bell Telephone Laboratories, New York, N. Y.

In the new resistor, the element boron, as well as carbon, is pyrolytically deposited in a thin film on a suitable ceramic core. The addition of this element, it has been found, gives considerably lower temperature coefficients of resistance than those possessed by plain carbon resistors as well as good stability. In addition, the new borocarbon resistors provide access to resistance ranges heretofore impossible to attain in stable and accurate film-type resistors.

While primarily developed for high-frequency applications, the pyrolytic carbon resistor possesses other characteristics which have led, and are leading, to greatly expanded fields of application. Principal among these characteristics are the tolerances of one per cent or better attainable in production, the stability in use, the relatively small and predictable temperature coefficient of resistance, and the low noise level. These properties result in large part from the ultimate crystalline structure of the carbon films.

Pyrolytic carbon films are composed of graphite-like crystallites which are on the average only one-ten-millionth of an inch in diameter and half as thick. The crystallites are so closely and randomly packed together that all resemblance to graphite is lost. Pyrolytic carbon is much harder than carborundum and leaves no smear when rubbed on paper as does graphite itself. Structural and analytical studies have shown, however, that each crystallite is surrounded by a skin or layer of complex hydrocarbons which separates it from its neighbors. This hydrocarbon skin increases the specific resistance and the temperature coefficient of resistance of pyrolytic carbon relative to graphite, which, along certain crystal axes, is a good metallic conductor. Decrease in the thickness of this skin or in the total volume it occupies results in a decrease in both the specific resistance and the temperature coefficient of resistance of pyrolytic carbon films.

The specific resistance of borocarbon films depends on their boron contents, and, by suitable variation in composition, films of very high resistances per square can be produced. Values of 500,000 ohms per square are readily obtained and values in excess of 1,000 megohms per square have been studied. The temperature coefficients of resistance for these high-resistance films are larger than for films of lower resistance but in the extremely high resistance ranges made accessible through use of these films, temperature variations are generally of lesser importance.

NBS Develops Thermostat for High Temperatures

An improved precision thermostat developed by Dr. W. R. Eubank at the National Bureau of Standards provides smooth, continuous control of an electric furnace within a very small range at temperatures between 1,000 and 1,550 degrees centigrade. The device is of the type in which the furnace winding itself serves as the sensitive element, forming part of a bridge circuit for control of a thyratron tube. The thyratron circuit then acts as a continuously variable valve, allowing just enough current to reach the furnace to compensate for a given temperature fluctuation. The new thermostat is highly sensitive and independent of normal fluctuations in line voltage. As it is convenient to operate, easily adjusted for any temperature, and reliable for periods of continuous operation from a few minutes to several days, it should provide a useful research tool in such fields as metallurgy, ceramics, glass technology, and cement chemistry, where automatic control of furnace temperatures has long been a problem.

In the Bureau's thermostat, the output of an a-c bridge, one arm of which serves as a resistance thermometer and as a heater element for the furnace, is amplified and applied to the control grid of a thyratron. When the resistance of the furnace winding changes slightly with temperature, the resulting unbalance of the bridge produces a difference in phase between the control voltage and the anode voltage of the thyratron. This phase difference determines the firing period of the thyratron and the thyratron action is reflected to the bridge circuit through a transformer, thus controlling the amount of energy supplied to the furnace.

The thyratron controls the furnace current by changing the impedance of the primary winding of the transformer. If the phase of the control voltage is such that no plate current flows in the thyratron, the transformer is unloaded and its impedance is high. Under these conditions, a negligibly small magnetizing current flows in the primary. When the thyratron fires, however, the impedance of the primary becomes low relative to the variable resistance. The bridge current, and thus the current through the furnace, thereby is increased, nearly all of it passing through the primary of the transformer. Thus the transformer reflects the high-voltage low-current characteristics of the thyratron switch into the power circuit as a low-voltage heavy-current control.

An advantage in the use of the phase-

Electric furnace temperatures are maintained constant within a very small range at temperatures above 1,000 degrees centigrade by means of the improved thyratron regulator (left) developed at National Bureau of Standards

controlled thyratron is gradual or proportional control as contrasted to on-off control. Overshooting, which appears with on-off control, is greatly reduced. It is expected that the control circuit developed at the Bureau will find application in the regulation of other furnaces and in baths and heaters operating at lower temperatures. Heater elements, such as pure nickel or certain nickel-chromium alloys, which have sufficient change of resistance with temperature in the lower temperature ranges, would be required in the latter applications.

Van Leer Named to Civil Service Committee on Engineering

Dr. Blake R. Van Leer, president of the Georgia Institute of Technology, Atlanta, has been named to the new Advisory Committee on Engineering to the United States Civil Service Commission. The Georgia educator was suggested for this important position by the Engineers Joint Council.

The new committee was formed at the suggestion of the council and in line with the Commission's own desires for the purpose of seeking advice as needed on matters affecting position classification standards, recruitment qualification, and promotion policies as related to engineering personnel.

The objectives of the new committee are as follows:

1. To recommend to the Classification Division and to the Examining and Placement Division changes in practices, policies, or procedures which it is believed will place the recruitment, placement, and development of engineering personnel on a sounder basis.
2. To explore with the Commission implications of major changes in the field of personnel administration, as they affect professional engineers.
3. To advise the Commission on programs and plans designed to improve Federal personnel administration of engineering personnel through a better understanding on the part of officials, employees, and citizens of the problems and purposes of the Federal government's merit system.
4. To advise the Commission's two divisions previously mentioned in the determination of policies and programs for adequately filling key engineering positions, and to advise them on problems of bringing into and keeping in the Federal service the type of engineers which it must have if its work is to be performed efficiently.
5. To assist the two divisions in their efforts to develop programs designed to improve the competence of administrative and supervisory personnel dealings with engineers and associated employees.
6. To provide the Commission with objective appraisals as to the effectiveness of the operations of the two divisions so far as they affect the recruitment, placement, promotion, retention, and development of engineering personnel in the Federal service.

RCA Announces 15-Inch Duocone High-Fidelity Loudspeaker

A new 15-inch duocone loudspeaker designed for high-quality reproduction at both high- and low-power levels has been announced by the Radio Corporation of America Tube Department. The new loudspeaker is of the permanent-magnet type, features high sensitivity between 40 cycles and 12,000 cycles, and is capable of handling 25-watts input. It is intended particularly for use in equipment such as high-quality radios, phonographs, and television receivers and monitors.

The design of the new *RCA-515S2* loudspeaker provides the advantages of both single- and dual-cone speakers but, at the same time, avoids disadvantages of conventional 2-cone loudspeaker construction such as distortion resulting from crossover interference.

The loudspeaker employs a magnetic structure with a vibrating system consisting of a large cone and a small cone mounted so that, for all practical purposes, the large cone is a continuation of the small cone. It is the duocone arrangement which avoids the crossover interference characteristic of conventional high-low loudspeaker combinations in which the woofer and tweeter are spaced apart. In the duocone arrangement each cone is mounted in its own housing and is driven by its own voice coil operating in its own air gap.

A 3/4-inch voice coil drives the small cone to produce the high frequencies, and a 2-inch coil drives the large cone to produce the low frequencies. The small cone does not vibrate at the lower audio frequencies because of the high reactance of the coupling capacitor at these frequencies. This design eliminates the need for the usual multielement crossover electric network since only the coupling capacitor is required to prevent excessive low-frequency power from damaging the high-frequency voice coil.

The unusual magnetic structure of the new loudspeaker utilizes a single 2-pound Alnico-V magnet arranged with the pole pieces and yoke so that the magnetic paths form a bridge network to provide each air gap with equal flux density. Both air gaps are excited by the single Alnico-V magnet.

High-Frequency Measurements Conference Slated for January

The second High-Frequency Measurements Conference sponsored jointly by the AIEE, the Institute of Radio Engineers, and the National Bureau of Standards will be held in Washington, D. C., January 10 to 12, 1951. Conference Headquarters will be at the Hotel Statler with the technical sessions held in the auditorium of the Department of the Interior. The Conference program will include about 25 outstanding technical papers, an evening demonstration of a spectacular nature, a luncheon, and conducted inspection tours of selected local and nearby scientific institutions. Chartered busses will provide transportation to the auditorium and for the inspection tour.

This High-Frequency Measurements Conference will be a forum at which the nation's leading engineers from educational, governmental, and industrial laboratories will exchange information on progress since the successful 1949 Conference. While most of the papers will deal with measurements in high-frequency through extremely high-frequency regions, some interesting video measuring techniques will be disclosed. Preprints and Proceedings are being dispensed with to encourage active workers to report their latest findings.

The Conference is under the general direction of the Joint AIEE-IRE Committee on High-Frequency Measurements of which Professor Ernst Weber of the Microwave Research Institute of the Polytechnic Institute of Brooklyn is Chairman. Dr. Harold Lyons of the National Bureau of Standards is Chairman of the Local Arrangements Committee, and Dr. Frank Gaffney of the Polytechnic Research and Development Company is Chairman of the Technical Program Committee. Finances are being handled by Ivan Easton of General Radio Company and publicity by E. P. Felch of the Bell Telephone Laboratories.

Most appropriately, this is the first scientific gathering of national scope to be brought to Washington in 1951 in celebration of the Semicentennial of the National Bureau of Standards.

The Bureau's contributions in the field of high-frequency measurements are legion. Pioneers of the early days of radio will recall when the Bureau's publication, "Radio Instruments and Measurements," perhaps better known as "Circular 74," was the bible of the budding industry. From its first printing in 1918 until the advent of radar, it held its place as the most authoritative reference on high-frequency measurements.

The standard frequency and time services broadcast by the Bureau's Stations *WWV* and, more recently, *WWVH*, have been of inestimable value both in peace and in war in tying measurements of frequency throughout the nation to a single standard.

The Bureau's recent work on Microwave Spectroscopic Frequency Standards and Measurements not only has attracted considerable attention in scientific circles but also has been widely heralded in the public press as paving the way for an "Atomic Clock" with a constancy exceeding that of the earth's rotation.

Ebasco Services Sign Power Contract with Greek Government

Representatives of Ebasco Services, Inc., New York, N. Y., recently signed a management contract with the Greek Government calling for the first stage in the development of a $200,000,000 nation-wide electric power system for Greece.

Under the 5-year contract, Ebasco will manage the design, construction, and operation of the modern power system. The estimated cost of the initially authorized projects is about $83,000,000. The Economic Co-operation Administration is assisting in the financing of the program and part of the funds to be used already are available through present ECA allocations and part under an agreement of co-operation between the Greek and Italian Governments.

The first steps in the program include a new 68,000-kw lignite-burning thermal-electric generating station on the Eubean Gulf, near Alaveri; a new 40,000-kw Agra Hydroelectric Generating Station on the Vodas River; a new 50,000-kw Ladhon Hydroelectric Generating Station on the Ladhon River; and a new 5,000-kw Louros Hydroelectric Generating Station on the Louros River.

The system also will include about 700 miles of 150,000-volt transmission lines—the first stages of a national grid connecting all generating plants and serving a major part of the continental area of Greece. Many new substations and distribution systems will be included in this first stage of the power development program. Also, improvements will be made to the small electric systems which will remain isolated until it is economical to connect them to the main power system and to the systems on the several islands in the Kingdom of Greece.

Oak Ridge Offers Courses in Use of Radioisotopes

The 18th, 19th, and 20th courses in the techniques of using radioisotopes in research will be given by the Special Training Division of the Oak Ridge Institute of Nuclear Studies during the winter and spring of 1951. Dates for the courses are as follows: January 8–February 2, February 19–March 16, and April 16–May 11.

The courses are designed to acquaint research workers with the safe and efficient use of radioisotopes in research. The course will consists of laboratory work, lectures on laboratory experiments, general background lectures, and special-topic seminars. Experiments are conducted covering the use and calibration of instruments, the purification and separation of radioactive materials from inert and other radioactive materials, measurement and use of carbon-14, pile activations, radioautographs, and the like. Seminars include such topics as the use of radioisotopes in animal experimentation and in humans, principles and practice of health physics, design of radiochemical laboratories, effect of radiation on cells, and similar topics.

The Special Training Division can accommodate 32 participants at each of the three courses. A registration fee of $25 is charged and participants will bear their own living and traveling expenses.

Additional information and application blanks may be obtained from Dr. Ralph T. Overman, Chairman, Special Training Division, Oak Ridge Institute of Nuclear Studies, Post Office Box 117, Oak Ridge, Tenn.

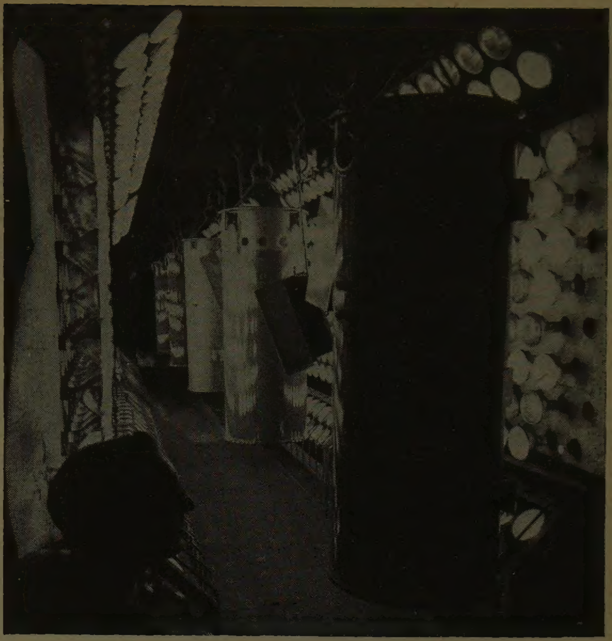
Iceland Expands Power Supply and Gains Large X-Ray Machine

The Government of Iceland has launched a power expansion program that will nearly double that nation's supply of electricity, and, in addition, yield a valuable X-ray machine for medical treatment. Hydroelectric generating equipment has been ordered from Westinghouse Electric International Company to serve Iceland's two main population centers, Reykjavik, the capital, and Akureyri, the textile center.

A 150,000-volt X-ray machine has been ordered with the power apparatus to enable inspection of the welded-steel penstock that will be constructed at the Akureyri station. When the penstock is completed, the X-ray machine will be modified slightly and then turned over to Iceland's Ministry of Health to be used for medical treatments.

Two 21,000-horsepower waterwheel turbine generators and auxiliary equipment will be installed in a new underground Reykjavik power station that will be built 32 miles from the capital at Iru Falls, on the Sog River. Natural penstocks cut in lava rock will furnish water power for the two generators. After leaving the turbines, the water will flow through a tunnel under a bend in the river, discharging below Kistu Falls to provide turbines with additional head. A third turbine generator will be installed in the future. On the northeast coast, an 11,500-horsepower generator will be installed near the Bruar Falls to supply power for Akureyri.

When completed, the two projects will add 54,500 kw to Iceland's installed capacity. Present installed capacity is approximately 55,000 kw.


Transformer tanks emerging from an oven after the first coat of the new Westinghouse 3-coat paint system has been applied

Westinghouse Develops 3-Coat Paint System for Transformers

The life of the finish on Westinghouse distribution transformers has been more than doubled by a 3-coat paint system which has been given the name "Coastal Finish." Each coat functions co-operatively with the others to withstand the oxygen, acids, salts, and alkalies found in seacoast and industrial atmospheres. The 3-coat system is applied in the same manner as standard finishes and, in production, is baked on for speed.

The prime or first coat applied to a prepared surface is composed of a vehicle giving good adhesion with desired flexibility and chemical resistance to salts, acids, and alkalies. The pigments used are primarily zinc chromate and iron oxide.

The second or intermediate coat is composed of modified phenolic and alkyd resins. These are chosen for resistance to heat, oxygen, salts, acids, and alkalies in concentrations generally encountered in the atmosphere. The pigment is composed of selected mica flakes which overlap each other in the film and produce a "shingle-roof" effect to further ward off moisture and oxygen.

The third and final coat is composed of resins and pigments to withstand the elements and to provide good appearance when new and after weathering has taken place. The final coat enhances the resistance of the other two coats.

ASCE Plans Centennial of Engineering for 1952

Plans are under way to celebrate the American Society of Civil Engineers Centennial of Engineering in Chicago, Ill., in 1952. In addition to civil engineering, the celebration will include the entire engineering field with the other societies joining forces to produce an event of international significance.

The celebration, which will include an exposition and a convocation of engineers, will occupy the approximate period of July 1 to September 30, 1952, and will be centered in the Museum of Science and Industry in Jackson Park, Chicago.

According to preliminary plans, the observance will consist of a variety of activities for both the general public and the professional engineer. Opening in early June will be a new permanent educational exhibit installation designed to bring home to visitors the tremendous contributions made by engineering during the past 100 years to the development of the nation and the elevation of the American standard of living. There will be appropriate temporary exhibits by engineering and industrial firms.

The convocation of engineers is scheduled to take place between September 3 and 13, and it is expected that this will be the largest ever held. Each of the other Engineers Joint Council constituent societies has accepted an invitation to unite with ASCE in the Centennial Celebration and each society is planning to hold a full-scale meeting during the convocation period. The American Institute of Architects and the Engineering Institute of Canada already have taken formal action to participate. Nearly a hundred other national, international, and regional engineering societies will take part, as will many engineering schools. The Department of State has stated its intention of collaborating with the Centennial in arranging for participation of foreign and international engineering organizations.

AEC Releases 27 Patents and Patent Applications to Public

Descriptions of 23 patents and 4 patent applications owned by the United States Government and held by the Atomic Energy Commission have been transmitted to the United States Patent Office for registry and listing in the Official Register of Patents.

The Commission will grant nonexclusive royalty-free licenses on the listed patents and applications as part of its program to make nonsecret technological information available for use by industry. A total of 165 patents and patent applications has now been released for licensing.

The list of patents giving number, title, inventor, and abstract, as well as applications for licenses, are available from the Chief, United States Atomic Energy Commission, Washington 25, D. C.

Indian International Exhibition to Be Held in January of 1951

The Ministry of Works, Mines, and Power of the Government of India is conducting an exhibition of engineering activities in the fields covered by the following international meetings: The Fourth Congress on Large Dams, The Sectional Meeting of World Power Conferences, The Meeting of the International Association of Hydraulic Research, and the International Commission on Irrigation and Canals. Both the meetings and the exhibition will be held in January of 1951.

The exhibition is being planned to show and demonstrate, as far as possible, the latest developments in the sciences and techniques covered by the international conferences.

All information pertaining to the exhibition can be obtained from the Secretary, Indian International Engineering Exhibition, Curzon Road Barracks, New Delhi, India, or from the Consulate General of India, 3 East 64th Street, New York 21, N. Y.

ECPD Holds Annual Meeting in Cleveland, Ohio

On October 20 and 21, 1950, the Engineers' Council for Professional Development held its 18th annual meeting at the Tudor Arms Hotel in Cleveland, Ohio.

A. C. Montieth, vice-president of the Westinghouse Electric Corporation and chairman of the ECPD Professional Training Committee, gave a report entitled "The First Five Years of Professional Development." Subcommittee reports were given by the following subcommittee chairmen: H. K. Breckenridge, Orientation and Training of the Young Engineer in Industry; J. C. McKeon, The Continued Education of the Graduate Engineer; K. B. McEachron, Jr., Integrating the Young Engineer into His Community; H. L. Solberg, Registration and the Young Engineer; A. R. Cullimore, Self-Appraisal Methods for Valuable Characteristics in Engineering; and D. P. Reynolds, Reading Lists.

Langmuir Appointed Atomic Energy Liaison Officer

Dr. David B. Langmuir, who has been a member of the staff of the General Manager, Atomic Energy Commission, has been appointed AEC Liaison Officer at Chalk River, Ontario, Canada. Dr. Langmuir will provide United States AEC liaison with officials of the Canadian Atomic Energy Program under the terms of the existing interchange agreement of the Combined Policy Committee.

From January 1948 to the present, Dr. Langmuir served as Executive Officer of the AEC Program Council, an advisory group to the General Manager composed of Directors of the five AEC program divisions. Previous to 1948, Dr. Langmuir served on the Joint Research and Development Board and with the Office of Scientific Research and Development. He also had been associated with the Radio Corporation of America as a research physicist.

Electrochemical Society Forms a Section for India

The Electrochemical Society, founded in 1902, is an international organization to promote the advancement of electrochemistry, electrometallurgy, electrothermics, electronics, and allied subjects. The membership is represented by scientists and engineers actively engaged in the various branches of electrochemistry.

An Indian section of this society was recently organized with headquarters at Bangalore. The section for India is the first to be formed outside the United States. The inaugural meeting of the new Indian section of the Electrochemical Society was held on March 23 and 24, 1950, at the Indian Institute of Science in Bangalore.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Numbering of Decade Bands

To the Editor:

I think that the AIEE Joint Subcommittee on Standard Frequency Bands and Designations did a very good job in the work on their Proposed Frequency Band Designations (*EE, May '47, pg 471,* and *August '49, pg 672*).

However, the thought occurred to me that a second step in the same direction would be an additional boon to the spectrum engineers without complicating life too much. The decade bands can be divided into nine subdivisions each—1 to 2, 2 to 3, 3 to 4, and so forth—enabling a uniform discussion of portions of the spectrum. These subdivisions would be numbered with a prefix before the band number. Thus, band 3–5 (read as three five) would be that band of frequencies whose lower limit is 300 kc and whose upper limit is 400 kc. The nomenclature follows the rule: The prefix defines the coefficient of the factor 10 and the band number (second number) defines the exponent of the factor 10. Thus, band 3–5 would designate the band whose lower limit is 3×10^5 cycles per second and whose upper limit is 4×10^5 cycles per second.

Confusion is eliminated from the system which used numbers and letters as mentioned in a previous manuscript. Unfortunately, the majority of engineers (much as they hate to admit it) don't remember the numerical position of more than the first five letters of the alphabet and would normally have to count to be certain that *g* is the seventh letter.

Likewise a system using subscripts either reverses the order of the coefficient and exponent, causing too much "thinking it out," or else tends to get away from the basic band numbers.

My proposed system would permit the differentiating in verbal conversation of subbands and bands, for example, 1–3 (one three) and 13 (thirteen).

CHESTER W. YOUNG

(Consolidated Vultee Aircraft Corporation, San Diego, Calif.)

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

A.S.T.M. STANDARDS ON ELECTRICAL INSULATING MATERIALS. A.S.T.M. Committee D-9 on Electrical Insulating Materials, January, 1950. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa. 657 pages, illustrations, diagrams, charts, tables, 9 by 6 inches, paper, $4.85. This book includes all of the standard and tentative test methods and specifications pertaining to the wide range of materials involved: insulating shellac and varnish; molded materials; insulating oils; ceramic products; plastics, textiles and paper; rubber; and mica products. Classified and numerical lists of the standards are provided for reference use.

A.S.T.M. STANDARDS ON RUBBER PRODUCTS. A.S.T.M. Committee D-11 on Rubber Products, April, 1950. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa. 652 pages, illustrations, diagrams, charts, tables, 9 by 6 inches, paper, $4.75. Over 100 standard and tentative test methods and specifications have been brought together in this book for reference and laboratory use. The methods cover chemical, physical, electrical, aging and weathering processibility, and low-temperature tests on rubber. Materials considered include automotive and aeronautical rubber, hose and belting, rubber coatings, latex foam and sponge, cements, and electrical insulating and protective equipment. Both a classified and a numerical index are provided.

DYKE'S AUTOMOBILE AND GASOLINE ENGINE ENCYCLOPEDIA. By A. L. Dyke. Twenty-second edition. Goodheart-Willcox Company, Chicago, Ill., 1950. 1,244 pages, plus Addenda Sections I-4, 120 pages, illustrations, diagrams, charts, tables, $9^{3}/_{4}$ by $6^{1}/_{2}$ inches, cloth, $7.50. A remarkably comprehensive collection of information on automobiles and internal-combustion engines is presented in this manual for the use of students, repairmen, and owners. Topics covered include the principles, description, and operation of all mechanical, propulsive, and electrical parts of an automobile, maintenance, testing and repair, specifications and definitions. The more than 100 pages of new and revised material contain 1949 specifications on a wide variety of items, and information on vacuum spark control, ignition distributors, dynaflow, and so forth. Many illustrations and a detailed 90-page index increase the utility of the book.

ELECTRICAL COMMUNICATION. By A. L. Albert. Third edition. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1950. 593 pages, illustrations, diagrams, charts, maps, tables, $9^{1}/_{4}$ by 6 inches, cloth, $6.50. This textbook covers the whole field of wire and wireless transmission of code, speech, and music. The basic subjects of acoustics, electroacoustic devices, networks, lines, cables, wave guides, and electronics are grouped in the first part of the book. Telephone, telegraph, and radio systems are dealt with in the later chapters. Major revisions in this edition have been made in the material on radio systems and dial telephone systems. Television is only briefly considered. Extensive lists of references are included.

ELECTROMAGNETIC FIELDS, Theory and Applications, Volume I. Mapping of Fields. By E. Weber. John Wiley and Sons, New York, N. Y.; Chapman & Hall, London, England, 1950. 590 pages, diagrams, charts, tables, $8^{3}/_{4}$ by $5^{3}/_{4}$ inches, cloth, $10.00. This book presents a survey of the methods of mapping the distribution of static electric and magnetic fields that can be derived from potential functions. Following a study of basic relations, the analytical, experimental graphical, and numerical methods are considered. These methods are applicable to problems of stationary heat flow, stationary flow of incompressible fluids, stationary electric current flow, and gravitation as well as to the major illustrations of electric and magnetic fields.

ELECTROMAGNETIC THEORY. By O. Heaviside with introduction by E. Weber. Dover Publications, New York, N. Y., 1950. 386 pages, diagrams, tables, $12^{1}/_{2}$ by 9 inches, cloth, $7.50. This reissue of a classic scientific work includes the three original volumes in one book by using somewhat oversize pages and a reorganized format. Suitable page numbering allows reference to the text from the original contents pages which are also included. A critical and historical introduction precedes the text together with a biography, both with lists of references to further reading.

ELEKTRISCHE MASCHINEN DER KRAFTBETRIEBE. By E. Wist. Springer-Verlag, Vienna, Austria, 1950. 184 pages, diagrams, charts, tables, $9^{1}/_{4}$ by $6^{1}/_{4}$ inches, linen, 21.50 D.M. A mathematical analysis of the characteristics and operation of electrical machines for power drives, with particular attention to starting, regulation and braking. Various types of d-c and a-c machinery are considered, and three examples of special electric drive installations are worked out. The book is intended not only to inform the student about these machines but also to assist in selecting the proper equipment for particular requirements.

DIE ELEKTROMAGNETISCHE SCHIRMUNG IN DER FERNMELDE- UND HOCHFREQUENZTECHNIK. By H. Kaden. Springer-Verlag, Berlin, Göttingen, Heidelberg, Germany; J. F. Bergmann, Munich, Germany, 1950. 274 pages, diagrams, charts, tables, 38 D.M. The problem of electromagnetic screening in long-distance communication and high-frequency technique is analyzed in considerable detail. The first and largest section deals with screening against interfering fields and covers not only screens with homogeneous walls but also discusses the effects of joints, slits, and other openings, and mesh screens. Part II covers screening against interfering currents. A thorough mathematical treatment is used.

L'ELETTRICITÀ NELL'AUTOMOBILISMO E NELL'AVIAZIONE. By M. Marchisio. Ulrico Hoepli, Editore, Milan, Italy, 1950. 282 pages, illustrations, diagrams, charts, tables, $11^{1}/_{4}$ by $8^{1}/_{4}$ inches, paper, Lire 1,200. This textbook on electrical equipment for automotive use covers the construction, characteristics, and operation of magnetos, storage batteries, battery ignition, spark plugs, starters, lighting, conductors and wiring, electrically operated accessories, and special control equipment for airplanes.

HIGH-SPEED COMPUTING DEVICES. By the Staff of Engineering Research Associates, Inc., supervised by C. B. Tompkins and J. H. Wakelin, edited by W. W. Stifler, Jr. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 451 pages, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, $6.50. This book is a discussion of the mechanical devices and electrical circuits which can be incorporated into computing machines. It is not a detailed comparison of various machines, although descriptions of certain American computers are given. The first part discusses the basic elements of machine computation. Part II is devoted to computing systems, and Part III to physical components and methods. References are placed at the end of each chapter, and there is an extensive bibliography on punch-card computing systems.

INDUSTRIAL INSTRUMENTATION. By D. P. Eckman. John Wiley and Sons, New York, N. Y.; Chapman & Hall, London, England, 1950. 396 pages, diagrams, charts, tables, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, cloth, $5.00. This book reviews the principles of the methods of measurement employed in industrial processing and manufacturing. Primary emphasis is given to the method rather than to the mechanism, and the fundamentals of physics pertaining to the problems of measurement are reviewed. Methods of applying instrumentation to processes are presented with the arrangement and selection of instruments, process analysis, and supervision of equipment. Mechanical, chemical, and electrical applications are covered, including spectrographic, strain gauge, and high-vacuum instrumentation.

(The) INELASTIC BEHAVIOR OF ENGINEERING MATERIALS AND STRUCTURES. By A. M. Freudenthal. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1950. 587 pages, illustrations, diagrams, charts, tables, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, cloth, $7.50. This book provides a fundamental approach to the subject with main emphasis on the physical response of engineering materials to forces, time, and temperature. Following an examination of basic concepts, the structural and phenomonological framework of the theory of elasticity is developed. The remaining sections are devoted to selected problems of the mechanics of the inelastic continuum, to the design of engineering structures, and to mechanical testing.

(The) INTEGRATED POWER SYSTEM. By P. Sporn. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 157 pages, illustrations, diagrams, charts, maps, tables, $8^{1}/_{4}$ by $5^{1}/_{2}$ inches, linen, $4.00. This book is intended to present the basic principles, economic advantages and disadvantages, and limitations of the integrated power system as the basic mechanism for power supply. The several chapters deal respectively with social-economic objectives, technical bases and requirements, components and tools, co-ordinating personnel, interconnections between systems, and economic problems. No detailed technical discussions are included, but an existing system is considered in the light of the principles set forth in the book.

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ENGINEERING Societies Library books may be borrowed by mail by AIEE members for a small handling charge. The library also prepares bibliographies, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Ralph H. Phelps, Director, Engineering Societies Library, 29 West 39th St., New York 18, N. Y.

INTERNAL BALLISTICS OF SOLID-FUEL ROCKETS, Military Rockets Using Dry-processed Double-base Propellant as Fuel. By R. N. Wimpress. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 214 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, $4.50. This book is concerned primarily with the utilization of solventless-processes double-base smokeless powder in artillery rockets of relatively short burning time. Including a considerable amount of previously unpublished information, it contributes substantially to the extension of the theory of rocket-motor performance. Other problems associated with rocket-motor design, such as ignition, nozzles, heating of motor walls, and test methods, are also considered, and pertinent experimental results are presented.

MANPOWER ECONOMICS AND LABOR PROBLEMS. By D. Yoder. Third edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 661 pages, diagrams, charts, tables, maps, $9^{1}/_{4}$ by 6 inches, cloth, $5.00. This book deals with the human resources of modern society and the problems which arise in the employment of manpower. It considers manpower goals, historic patterns of manpower conservation, industrial unrest, wages, job markets, employment conditions, collective bargaining, policies and practices of labor organizations, and constructive industrial relations. Exercises and questions follow each chapter.

MATHEMATISCHEN THEORIE ELEKTROMAGNETISCHER SCHWINGUNGEN. By C. Müller. Akademie-Verlag, Berlin, 1950. 55 pages, diagrams, tables, $11^{1}/_{2}$ by $8^{1}/_{4}$ inches, paper, 7 D.M. A detailed mathematical treatment is presented of the theory of electromagnetic vibrations in homogeneous and inhomogeneous media. In the chapter on homogeneous media, sections are devoted to a treatment of the Huygens' principle, radiations, and intermittent flow. The chapter on inhomogeneous media considers physical-heuristic observations and a setting up of integral equations.

MATRIZEN. By R. Zurmühl. Springer-Verlag, Berlin, Göttingen, Heidelberg, Germany, 1950. 427 pages, diagrams, charts, tables, $9^{1}/_{4}$ by $6^{1}/_{4}$ inches, cloth, 25.50 D.M. Designed particularly for engineers, this mathematics text provides effective coverage of matrix calculations. The several chapters deal with the basic transformations, rank and linear dependance, bilinear and quadratic forms, eigenvalue problems, matrix structure, numerical processes for equation solution, and the application of matrix calculations to electrochemistry, vibration problems, adjustment of errors, and other technical fields.

MISURE ELETTRICHE, Volume I, Misure Elettriche Industriali. Libreria Editrice Politecnica, Cesare Tamburini, Milan, Italy, 1950. 448 pages, illustrations, diagrams, charts, tables, $9^{3}/_{4}$ by 7 inches, paper, Lire 3,700. This book provides a comprehensive survey of the instruments and methods used in the industrial measurement of electricity and electric circuits. Both the theoretical and constructional aspects are dealt with, with considerable attention to specialized cases.

MODERN PLASTICS ENCYCLOPEDIA AND ENGINEER'S HANDBOOK 1950. Plastics Catalogue Corporation (Breskin Publications), 122 East 42nd Street, New York 17, N. Y. 1,212 pages, illustrations, diagrams, charts, tables, $11^{1}/_{2}$ by $8^{1}/_{2}$ inches, cloth, $3.00. The Engineering Section of this extensive compilation, considerably expanded in the new edition, has four parts as follows: molding design factors; molding, extruding, and casting; fabricating and finishing; machinery. Important commercial types of plastics are covered in separate chapters in the Materials Section, followed by information on film and sheeting, laminates and laminating. The Technical Data Section contains a group of annually revised charts, including the comprehensive Plastics Properties Chart, standard specifications, statistics, and bibliographies. There is a Directory Section with classified and indexed lists of manufacturers of plastics and equipment.

PHYSICAL CHEMISTRY of ELECTROLYTIC SOLUTIONS (American Chemical Society Monograph Series, Number 95). By H. S. Harned and B. B. Owen. Second edition revised and enlarged. Reinhold Publishing Corporation, New York, N. Y., 1950. 645 pages, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, $10.00. The first five chapters are theoretical and deal with general thermodynamics, the basic interionic attraction theory, and ionic solutions in equilibrium and in perturbed states. The succeeding five chapters contain discussion of experimental methods for the study of electrolytes. The last five chapters cover the properties of electrolytes, such as hydrochloric acid, 1–1, and polyvalent electrolytes, with separate chapters devoted to mixtures of strong electrolytes and to weak electrolytes.

PROTECTIVE COATINGS for METALS. By J. W. Gailer and E. J. Vaughan. Charles Griffin and Company, Ltd., London, England, W. C. 2, 1950. 261 pages, diagrams, tables, 9 by $6^{1}/_{4}$ inches, fabrikoid, 24s. The most important of the various metallic and nonmetallic films or coatings which are applied for the protection of the more commonly used metals are described. The theory of the action of each protectant is explained and the methods of application specified in detail. Emphasis is placed on a scientific choice of coatings for a particular environment. General aspects of inspection are considered in the appendices. Summary tables provide data on the better-known coatings. A list of references is included.

RADIO ENGINEERING HANDBOOK. By K. Henney, editor-in-chief. Fourth edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 1,197 pages, illustrations, diagrams, charts, maps, tables, $9^{1}/_{4}$ by $6^{1}/_{4}$ inches, cloth, $10.00. Principles, standards, procedures, and design data are provided covering the whole field of radio communication from fundamentals to special applications, including television and facsimile. New subjects dealt with in this edition include: cavity magnetrons, radar and loran, sequential scanning, crystal converters, disk seal tubes, lobe switching, and so forth, and there is a new section which takes up in detail the physical, mathematical, psychological, and acoustical bases on which electrical communication exists.

RESISTANCE WELDING, Designing, Tooling and Applications. By W. A. Stanley. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 329 pages, illustrations, diagrams, charts, tables, $11^{1}/_{4}$ by $8^{3}/_{4}$ inches, linen, $7.50. The basic purpose of the book is to assist designing and manufacturing engineers in the development of their own ideas of how metal-made products may be more economically and efficiently produced. Equipment, materials used, design, tooling, and production techniques are all discussed. Material is included on spot welding, projection welding, seam welding, and flash butt welding. The nearly 800 illustrations include a wide range of specialized fabrication procedures.

LA TECHNIQUE DU CHAUFFAGE ÉLECTRIQUE, Volume I, Theories et Calculs. By C. Frérot. Gauthier-Villars, Paris, France, 1950. 503 pages, diagrams, charts, tables, 10 by $6^{1}/_{2}$ inches, paper, 2,300 frs. This treatise on the technique of electric heating covers both industrial and domestic applications. Part I gives a summary of the generalities and development of electric heating. Part II deals with the transformation of electric energy to heat energy. Part III covers the resistance of metals to electric current, the characteristics of alloys for resistance wiring, and types of heating elements. Part IV covers electric boilers, the decomposition of water by electric current, and the resistivity characteristics of water. Part V discusses heat transmission, steam accumulators, and the storing of heat energy.

WERKZEUG-HANDBUCH ÜBER SCHNEIDWERKZEUGE FÜR DIE METALLBEARBEITUNG. By F. Pütz. Carl Hanser Verlag, Munich, Germany, 1950. 418 pages, illustrations, diagrams, charts, tables, 8 by 6 inches, cloth, 34 D.M. This book is a guide for the purchaser of tools and an aid to the engineer and machinist in the correct selection of the proper tool for a specific application. The characteristics, applications, and limitations of various types of drills, reamers, milling, cutting, threading, and other tools are discussed. The efficiency of various tool steels in the machining of different metals and alloys is brought out. A section on maintenance and care of tools is included.

GRUNDZÜGE DER ANGEWANDTEN GEOELEKTRIK. By V. Fritsch. Manzsche Verlags- und Universitätsbuchhandlung, Vienna, Austria, 1949. 412 pages, illustrations, diagrams, charts, tables, 9 by 6 inches, paper, $10.50; bound, $11.25. Considers the characteristic features of the electrical properties of the subsoil. Following a discussion of geologic conductors and general information on geoelectric measurements, the procedures for using direct current and low, medium, and high alternating currents for geological study are presented. Both theoretical aspects and practical examples are given. A bibliography is included.

GRUNDZÜGE DER TENSORRECHNUNG IN ANALYTISCHER DARSTELLUNG. Teil II, Tensoranalysis. By A. Duschek and A. Hochrainer. Springer-Verlag, Vienna, Austria, 1950. 338 pages, diagrams, 8 by $5^{1}/_{2}$ inches, paper, $6. This second volume of a set of three discusses the application of tensor analysis to two seemingly separate fields. The first is the differential geometry which covers the theory of curves and surfaces of Euclidian space as well as the principles of Riemann's geometry. The second is the theory of fields which also presents an introduction to the theory of potentials and their boundary problems. Both fields are occasionally treated in the same sections.

HIGH-FREQUENCY INDUCTION HEATING. By F. W. Curtis. Second edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 389 pages, illustrations, diagrams, charts, tables, $8^{1}/_{4}$ by $5^{1}/_{2}$ inches, cloth, $6. Explains the fundamental electrical principles of an important technique of applying heat in the production of metal parts. Localized hardening and the joining of metal assemblies are the principal uses considered. In this revised second edition, a comprehensive analysis of coil design and new material on fixture designs are included. Types of steel best suited to induction hardening, various means of quenching, soft solders, brazing alloys, and fluxes are all fully treated.

JOSEPH HENRY, HIS LIFE AND WORK. By T. Coulson. Princeton University Press, Princeton, N. J., 1950. 352 pages, illustrations, diagrams, tables, $9^{1}/_{2}$ by $6^{1}/_{4}$ inches, $5. In narrative style the author presents a critical account of the achievements of Joseph Henry. One of America's foremost scientists, he is remembered not only for his extensive and important discoveries in the field of electromagnetism, but also for his organization of the Smithsonian Institution and his development of the Weather Bureau. All this is dealt with in such a way as to give a picture of the man, as well as a demonstration of his importance both in his own time and afterward.

LES PETITES TURBINES HYDROÉLECTRIQUES MODERNES. By H. Lanoy. Girardot and Cie., 27 Quai des Grands-Augustins, Paris 6°, France, 1949. 80 pages, illustrations, diagrams, charts, tables, $8^{1}/_{2}$ by $5^{1}/_{4}$ inches, paper, 360 frs. The utilization of hydraulic turbines in small streams and waterfalls for the production of electric power is discussed. Equipment and operating characteristics are described. Applications are indicated, including an example of installation for rural service. The history of hydraulic turbines is briefly covered.

PROBLEMS IN PERSONNEL ADMINISTRATION. By R. P. Calhoon. Harper and Brothers, Publishers, New York, N. Y., 1949. 540 pages, tables, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, cloth, $5.50, regular trade edition; $4 college text edition. In contrast to the usual text on this subject which deals with techniques and practices this book emphasizes problem analysis, problem handling, and actual administration of the various personnel functions. Among the topics treated are: work load and job assignment; writing and administering policies and procedures; problems of interpreting legislation; the personnel administration and collective bargaining; and safety administration. Numerous problems, projects, and demonstrations are included.

QUALITY CONTROL AND STATISTICAL METHODS. By E. M. Schrock. Reinhold Publishing Corporation, New York, N. Y., 1950. 213 pages, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, $5. Intended for those who are new to the field, or relatively so, this book provides a logical approach to the effective appraisal and control of product quality. The basis and development of quality control charts are shown, and their use for and under various conditions is demonstrated both in the text and graphically. Acceptance sampling and sequential analysis are dealt with briefly in separate chapters. The methods given in the book have a wide range of industrial application.

STETIGE REGELVORGÄNGE, (Bücher der Technik). By W. Oppelt. Wissenschaftliche Verlagsanstalt K. G. Hannover in Gemeinschaft mit Wolfenbütteler Verlagsanstalt G.m.b.H. Wolfenbüttel, 1949. 144 pages, diagrams, charts, tables, $8^{1}/_{4}$ by 6 inches, stiff cardboard, DM 7; half linen, DM 7.80. This book provides an introduction to the fundamentals of automatic control. Both simple and complex control circuits are analyzed, and examples of actual circuits are given. A bibliography is included.

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Plastics Research and Technology at the National Bureau of Standards. Summarizes the activities of the Bureau in the field of plastics since 1917. The plastics program is presented under eight different headings: properties of plastics, testing of plastics, plastic materials, applications of plastics, specifications for plastics, general information on plastics, and investigation of German technology. Illustrated. 14 pages. Available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 15 cents a copy.

Printed Circuits—Final Report. Discusses characteristics of special components, materials, and construction details of design, particularly with relation to the high-temperature requirements that necessitated development of a special adhesive-tape-type resistor capable of operation at 200 degrees centigrade. 99 pages including photographs, drawings, graphs, and tables. $1.75 per copy. This printed circuits data pamphlet is available from the Office of Technical Services, Department of Commerce, Washington 25, D. C.

Electronic Miniaturization. Divided into two general parts. The first deals with the design and production of wide-band intermediate-frequency amplifiers and the second covers the general problems of subminiaturization such as temperature and insulation requirements, capacitors, conducting paints, wire and solder, potted and molded assemblies, inductors and transformers, subminiature tubes, and sources of subminiature components. Includes photographs, diagrams, and charts. 189 pages. Available from the Office of Technical Services, Department of Commerce, Washington 25, D. C., at $4.75 per copy.

Nuclear Data. Presents a comprehensive collection of experimental values of half-lives, radiation energies, relative isotopic abundances, nuclear moments, and cross sections. 310 pages. The price of $4.25 includes three supplements which the purchaser will receive automatically at 6-month intervals. This nuclear data book is available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Surface Waves and their Application to Transmission Lines. Discusses the investigation of surface waves on a conductor having a plain surface and on a conductor having a modified surface, particularly a dielectric coating; and the efficiency of a launching device for such waves. 47 pages including calculations and graphs. $1.25 per copy. This pamphlet is available from the Office of Technical Services, Department of Commerce, Washington 25, D. C.